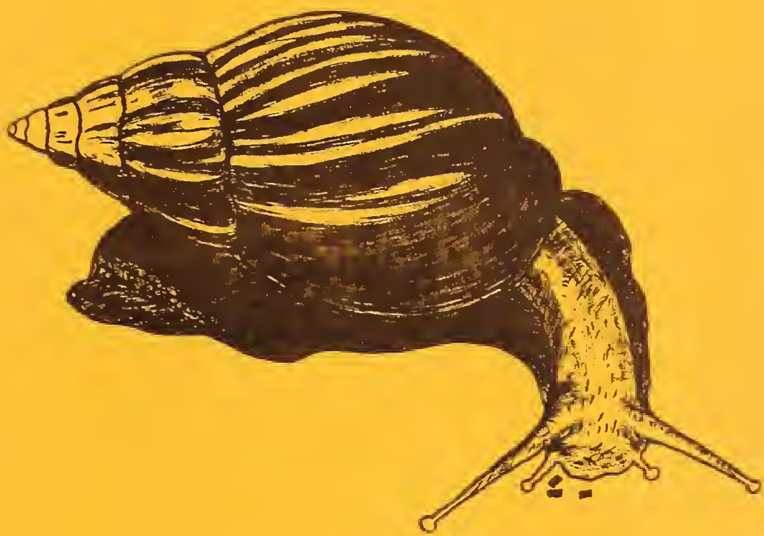
THE SCREENING OF CANDIDATE MOLLUSCICIDES AGAINST THE GIANT AFRICAN SNAIL, *ACHATINA FULICA* BOWDICH (STYLOMMATOPHORA: ACHATINIDAE)



By

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United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine Programs

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THE SCREENING OF CANDIDATE MOLLUSCICIDES AGAINST THE GIANT AFRICAN SNAIL, *ACHATINA FULICA* BOWDICH (STYLOMMATOPHORA: ACHATINIDAE)

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ABSTRACT

The screening of candidate molluscicides was started in January 1970 to support efforts of State and Federal agricultural workers trying to eradicate the giant African snail, _Achatina fulica_ Bowdich, from Miami, Florida. _A. fulica_ was introduced into Miami in 1966 by an 8-year old boy who returned from a vacation in Hawaii with three _A. fulica_ in his pockets.

The molluscicide, metaldehyde, has been used for the control of slugs and snails since it was discovered in the early 1930's. Metaldehyde has not given a sufficiently high degree of mortality of _A. fulica_ to insure eradication of the pest from Miami. The screening tests in Hawaii were conducted to find other more suitable molluscicides and methods which might aid containment and eradication of the infestation of _A. fulica_ in Miami, Florida.

During the screening period (January 1970 - April 1973), 107 compounds were screened. The candidate molluscicides were screened in four phases: Phase I, Initial Screening Tests; Phase II, Bait Screening Tests; Phase III, Field Tests; and Phase IV, Regulatory Treatment Development Tests.

The Phase I, Initial Screening Tests consisted of spreading a solution of candidate molluscicide (90 lbs. a.i./acre) uniformly over the surface of a 12" x 12" glass plate in a 12" x 12" x 3" deep, 1" mesh wire cage. Six _A. fulica_ (with shells of 6½ whorls, 50-80 mm long) were then placed on the plate for one week. The compounds giving 83-100% mortality in Phase I were made into 2% a.i. baits and tested at 3 lbs. a.i./acre in Phase III.

In the latter part of the testing period, the promising candidate molluscicides were made into 2%, 4%, and 8% a.i. baits and screened at 3, 6, and 12 lbs. a.i./acre respectively in Phase II. The same cage arrangement used in the Phase I screening tests was used in the screening of baits in Phase II.

The 2% a.i. baits giving 66-100% mortality in the Phase II tests were field tested at 3 lbs. a.i./acre in Phase III.

In the latter part of the Phase III test period, the 2%, 4%, or 8% a.i. baits giving the highest mortality in Phase II tests were field tested at 3, 6, and 12 lbs. a.i./acre respectively as dictated by the mortality results from Phase II. Phase III treatments were replicated three times with 11 adult A. fulica/replication.

The chemicals screened consisted of 46 carbamate, 23 organic phosphate, 19 salicylanilide, 6 tin, and 13 miscellaneous compounds. In the Phase I tests, 82.2% of the carbamate, 66.7% of the organic phosphate, 21.1% of the salicylanilide, 80% of the tin, and 14.3% of the miscellaneous compounds gave 50% or greater mortality of A. fulica.

Forty-eight candidate molluscicides (27 carbamate, 12 organic phosphate, 2 salicylanilide, 3 tin, and 4 miscellaneous compounds) were screened as baits in the Phase II bait tests. Sixteen (59.3%) of the carbamate, 5 (41.7%) of the organic phosphate, 1 (50%) of the salicylanilide, 2 (66.6%) of the tin, and 2 (50%) of the miscellaneous compounds tested in Phase II gave 50% or greater mortality of A. fulica.

Forty candidate molluscicides (21 carbamate, 9 organo phosphate, 2 salicylanilide, 4 tin, and 3 miscellaneous compounds) were tested in the Phase III field tests. Six (28.6%) of the carbamate, 1 (11.1%) of

the organo phosphate, 0 (0%) of the salicylanilide, 4 (80%) of the tin, and 1 (33.3%) of the miscellaneous compounds tested in Phase III gave 50% or greater mortality of A. fulica.

Carbamate compounds, Isolan®, Hercules 5727, Mesurol®, carbofuran, dixacarb, Union Carbide's UC-30044 and UC-30045, Ciba's C-9643 and C-10015, fenazaflor, formetanate HCl, Bay 78389, Shell's SD-8530, SD-17250, and SD-17578; organic phosphate compounds, disulfoton, phorate, Azodrin®, and Chevron Ortho® 9006; the salicylanilide, 3,4',5-tribromosalicylanilide; tin compounds, triphenyl tin acetate, triphenyl tin hydroxide, and Pennwalt TD-5032; and miscellaneous compounds, dinitrobultylphenol and metaldehyde demonstrated contact and stomach poisoning action against A. fulica.

Shell SD-17250, Union Carbide UC-30045, Pennwalt TD-5032, and triphenyl tin acetate were the most impressive candidate molluscicides screened.

Candidate molluscicides, Pyrolan®; carbanolate; Zectran®; carbaryl; aminocarb; Chevron RE-11775; Shell's SD-9098 and SD-15289; International Minerals & Chemicals, Inc. IMC-48003; pirimicarb (PP-062); Stauffer's R-15201, R-15206, R-15996, and R-16745; 2',4',6'-tribromo-3-nitro-salicylanilide; tributyl tin oxide; and methylene chloride demonstrated a moderate-high degree of contact poisoning action but a low degree of stomach poisoning action. Triphenyl tin hydroxide demonstrated a moderate degree of contact action and a very high degree of stomach poisoning action (50% and 97% mortality respectively).

The Miller's Liquid Sevin Insect Spray 10% formulation of carbaryl was highly ovicidal to eggs of A. fulica when applied as a 0.1% a.i.

drench treatment (100% mortality and/or nonhatch in Phase IV tests).

Methylene chloride and xylene, two common inert ingredients in emulsifiable concentrate insecticide formulations were highly molluscicidal (100% mortality of A. fulica exposed to 1% and 2% a.i. dip treatments).

A. fulica mortality from carbaryl in combination with methylene chloride was higher than when each was used alone.

The effects of xylene in combination with carbaryl were additive.

Carbaryl with methylene chloride, carbaryl, methylene chloride, and xylene 0.6% dip treatments gave 100%, 50%, 80%, and 50% mortalities of A. fulica respectively.

The Miller's Liquid Sevin Insect Spray 10% formulation was highly phytotoxic when used as a dip treatment of 0.1% a.i., but carbaryl, methylene chloride, and xylene were relatively nonphytotoxic when used alone in dip treatments of 1%, 1% and 5%, and 1% and 2% a.i. respectively.

All the compounds that qualified for additional testing were not necessarily tested. Chemicals that could not be obtained in the bait form or could not be obtained in sufficient volume to prepare baits were not fully tested.

The screening of candidate molluscicides indicated the use of baits alone is not sufficient to eradicate A. fulica. A combination hand-collecting and bait treatment program to kill the reproducing adults and drench treatment program to kill the eggs, infants, young, and possibly adults, is necessary for breaking the reproduction cycle.

Hand-collecting and baiting will kill the egg producers. Those not killed will become nonreproductive or sterile with time (1-2 years). The appropriate drench treatment will kill the eggs, infants, and young, preventing them from becoming egg producers and serve to activate those *A. fulica* in aestivation, making them vulnerable to hand-collecting and baiting.

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INTRODUCTION

The screening of candidate molluscicides was started in Hawaii in January 1970 to support efforts of federal and state agricultural workers trying to eradicate the giant African snail, *Achatina fulica* Bowdich, from Miami, Florida. *A. fulica* was introduced into Miami in 1966 by an 8-year old boy who returned from a vacation in Hawaii with three *A. fulica* in his pockets (Sturgeon, 1971).

The molluscicide, metaldehyde, has been used for the control of slugs and snails since it was discovered in the early 1930's. Bait containing metaldehyde 3.25% and calcium arsenate 5% a.i. has not given a sufficiently high degree of mortality of *A. fulica* to insure eradication of *A. fulica* from Miami.

The objective of the screening tests was to find more suitable molluscicides and methods to aid containment and eradication of the incipient infestation of *A. fulica* in Miami, Florida.

The giant African snail (Figs. 1-3) is native to East Africa. *A. fulica* spread to Madagascar prior to 1800, then to Mauritius (1800), India (1847), Ceylon (1900), Malaya (1911), Singapore (1917), Indonesia (1922-25), China (1931), Japan (1933) (establishment prevented by the Japanese Ministry of Agriculture and Forestry; does not occur in Japan), Hawaii (1936), Mariana Islands (1935-38), Hong Kong (1937), Thailand (1937), Philippines (1942), Burma (pre-1945), New Guinea (1945) (Mead, 1961), and Miami, Florida (1966) (CEIR, 1969b).

A. fulica belongs to the Phylum, Mollusca; Class, Gastropoda; Subclass, Pulmonata; Order, Stylommatophora; Family, Achatinidae; Genus, *Achatina*; Subgenus, *Lissachatina*; Species, *fulica*; and Subspecies, *fulica*.

Bequaert (1950) lists it as Achatina (Lissachatina) fulica fulica Bowdich. Bequaert reduced 20 variants of A. fulica to five subspecies:

Achatina fulica fulica Bowdich	-- nominate (named) subspecies (subgenotype)
Achatina fulica hamillei Petit	-- ancestral subspecies inhabiting East Africa
Achatina fulica castanea Lamarck	-- unusual color form variant
Achatina fulica coloba Pilsbry	-- dwarf variant
Achatina fulica rodatzi Dunker	-- albino variant

The giant African snail is called the Japanese snail in the Philippines (Choy, 1963), the Kalutara snail in Ceylon (Somander, 1951), and when it was being cultured in Japan it was called the edible snail (Esaki, 1942).

A. fulica is both a general scavenger and plant feeder. Through personal observations and review of literature (Abbott, 1948; Chamberlin, 1952; Choy, 1963; Herklots, 1948; Johnson, 1969; Kondo, 1950; Lange, 1950; Mead, 1961; Pangga, 1957; Rees, 1951; Schreurs, 1963; Williams, 1951; Cooperative Economic Insect Report (CEIR), 1965-1969a). Some 212 different plants fed on by A. fulica have been catalogued. A. fulica also feeds on crushed bodies of its own kind, other dead animals, decaying and rotting vegetation, dung, garbage, soil, wet soggy paper and cardboard, and whitewash.

Malacologists consider A. fulica to be the most economically important land snail pest known to man. Mead (1961) attributes the need for creating the separate discipline of economic malacology to A. fulica.

A. fulica is an intermediate host of the rat lungworm, Angiostrongylus cantonensis (Chen), which causes eosinophilic meningitis in man (Alicata, 1970). Mead (1961) suggests that A. fulica could also carry and spread plant diseases.

A. fulica is hermaphroditic. Each individual contains both the male and female reproductive organs and produces eggs. For all intents and purposes, cross-fertilization is necessary for the laying of a sufficient quantity of eggs to insure perpetuation of the species. Self-fertilization does occur but virgins usually lay less than 10 eggs at a time. Most of the eggs that a virgin lays are sterile. The probability of an individual maturing to reproduce from a self-fertilized egg is quite low.

A. fulica deposits single eggs over a continuous period of time so that the end effect is a clutch containing an average of 200 eggs.

Kekauoha (1966a, 1966b), in Hawaii, found that each mature A. fulica lays 5-6 clutches of eggs during a six-month laying season. The average interval between ovulation was 34 days. Egg incubation was 1-17 days.

Schreurs (1963), in West New Guinea, found that "under favorable conditions", A. fulica could go from egg to egg in 6½ months.

At hatching, the shell of the infant A. fulica is 5 x 4.5 mm and has 2½ whorls. Kondo (1952) considered A. fulica of 35 mm and over to be reproductive.

In captivity, an A. fulica lived for nine years (Herklots, 1948). Mead (1961) places the normal life span of A. fulica at five years.

Kondo (1964) believes aestivation by A. fulica is induced by two factors: (1) a seasonal physiological change and (2) factors adverse

to the snail, e.g., dry weather. Some *A. fulica* Kondo used in his studies in Hawaii aestivated from February-May. Ghose (1959) places aestivation at November-June in India.

In general, control of slugs and snails can be divided into natural control (climatic factors, topographic features, plant resistance, and natural enemies) and applied control (biological, mechanical, cultural, legislative, and chemical controls).

Basinger (1935) used a calcium arsenate bran bait for the control of the land snail, *Helix pisana* Müller, and the European brown garden snail, *Helix aspersa* Müller, in California. He determined that the bait was 92% effective against the *H. pisana* present and 96% effective against the active *H. pisana*, and 88% effective against the *H. aspersa* present and 98% effective against the active *H. aspersa*.

Lange, Jr., and MacLeod (1941) conducted bait tests against a gray garden slug, *Deroceras agreste* (Linnaeus); the greenhouse slug, *Milax gagates* Draparnaud; and the snail, *H. aspersa*, in California. They found that the most satisfactory baits were those that contained 1.5 to 2.5% metaldehyde with 5% calcium arsenate mixed with bran or fruit pulp.

Lange, Jr., and Sciaroni (1952) conducted tests against the gray garden slug, *Deroceras reticulatum* (Müller)(= *Agriolimax agrestis* Linnaeus), and *M. gagates*, using metaldehyde 3%, 5%, and 10% a.i. dusts and 5% metaldehyde-2% parathion dust. The dusts were applied directly on the slugs, on the leaves, and on glass plates exposed to the slugs. Metaldehyde 5% a.i. applied directly on the slugs and metaldehyde 2% and 5% a.i. applied to the leaves gave 100% slug mortality (5 days exposure). Parathion 2% a.i. dust applied directly on the slugs gave 20% mortality,

and parathion 2% a.i. applied to the glass plate gave 13.3% slug mortality. The 5% metaldehyde-2% parathion dust gave 86.7% and 13.3% slug mortalities when applied to slug and glass plate respectively (6 days exposure).

Lewis and Fullette (1942) ran bait tests against the land snail, *Helix aspersa* Müller, in California. They concluded that: calcium arsenate bait was more effective than metaldehyde and metaldehyde-arsenate bait; metaldehyde bait was relatively ineffective when broadcast and during cold weather (best effects in small piles in the sunshine); the best control coincides with rainy weather; and combination arsenical and metaldehyde bait was better than metaldehyde alone.

Howitt (1961), in California, conducted tests against a gray garden slug, *Deroceras agreste* (Linnaeus), and the black slug, *Arion ater* (L.), using 2.5% and 5% a.i. metaldehyde dusts and a 50% a.i. colloidal suspension. All treatments reduced the slugs in the field.

Howitt and Cole (1962), in Washington, conducted tests against the slugs, *Deroceras reticulatum* (Müller)(= *Agriolimax agrestis* Linnaeus), *Prophysaon andersoni* (Cooper), *Milax gagates* (L.), *Arion circumscriptus* (Johnston), and *Limax maximus* (L.). Metaldehyde sprays were superior to metaldehyde 1.75%-tricalcium arsenate 5% bait in controlling the slugs.

Richardson and Roth (1963 and 1965) conducted fumigation tests (for the U. S. Department of Agriculture) against the snails, *Theba pisana* (Müller) and *Cochlicella barbara* (L.) in aestivation, mainly with Carboxide® (ethylene oxide 10%-carbon dioxide 90%), ethylene oxide 11%-Freon® 89%, methyl bromide, Vikane® (sulfuryl fluoride), hydrogen cyanide, and chloropicrin. Other fumigants tested were acrylonitrile-carbontetrachloride (Acritect®), carbon disulphide, carbon tetrachloride,

ethylene dibromide, ethylene chlorbromide, methallyl chloride, Phostoxin® (hydrogen phosphide), Vapona® (dichlorvos), and paradichlorobenzene.

Cochlicella barbara (Linnaeus) was more difficult to kill. Most of the other materials were not satisfactory. Paradichlorobenzene showed considerable toxicity in a preliminary 24-hour test but more research was needed.

In Washington, Getzin (1965) conducted tests using Bay 37344 against Deroceras reticulatum (Müller)(= Agriolimax agrestis L.). Bay 37344 3% and 4% a.i. baits gave a higher mortality than did a metaldehyde 4% a.i. bait (up to 90% mortality with Bay 37344).

Hunter and Johnston (1970), in Cambridge, England, conducted tests against the slug, Agriolimax reticulatus (Müller). They determined the LD_{50} for Shell WL-21959, Lannate®, methiocarb, metaldehyde, formetanate, dimetan, dioxacarb, and PP-062 (pirimicarb). The chemicals were introduced directly into the alimentary canals of the slugs. They were interested in demonstrating the range of toxicity rather than finding a new slug-killing chemical.

In Oregon, Crowell (1967) conducted tests with experimental poison baits against Helix aspersa Müller and Arion ater (L.). The five experimental baits tested (Mesurol®, Tranid®, EP-332, EP-316, Dupont IN-1179) were more toxic than the standard metaldehyde bait.

Barry (1969) conducted tests in Ohio for the control of Deroceras reticulatum (Müller)(= Agriolimax agrestis L.) in corn fields. He evaluated carbaryl, phorate, Zectran®, Zinophos®, Frescon®, dinoseb, and Ortho Bug-geta® meal. Phorate (EC 1 and 1.5 lbs. a.i./acre) was the most effective (85-95% mortality). The Bug-geta® meal was

effective at 2 lbs. a.i. metaldehyde/acre (85% mortality). Zinophos® gave "a significant reduction 120-hour posttreatment". Frescon® at 0.45 lbs. a.i./acre gave 62-74% reduction of slugs in the field plots. Zectran® reduced the slug population but carbaryl did not (both applied at 1 lb. a.i./acre).

Judge (1969), in New York State, conducted screening tests of candidate molluscicides against the gray garden slug, Deroceras reticulatum (Müller)(= Agriolimax agrestis Linnaeus). His tests were conducted in two phases. In the first phase, slugs in cages were given disks of carrots treated with the 74 candidate molluscicides (0.1% a.i./gallon solution). In the second phase, slugs were caged on trays of growing peas which had been sprayed with 2 lbs. a.i./acre of the best materials from Phase I. Phase I materials were also screened against the gray field slug, Deroceras laeve (Müller). Eleven of 21 carbamate compounds (50%), 12 of 42 organo phosphate compounds (28.57%), 1 of 7 miscellaneous compounds (14.28%), and 0 of 4 organo chlorine compounds (0%) passed on to the second stage test. Of the four compounds giving over 60% mortality in Phase II tests, two were carbamate compounds, one was an organo phosphate compound, and one was a miscellaneous compound.

Gaaboub et al. (1972), in Egypt, compared the molluscicide, Niclosamid®, with the mosquito larvicides, fenthion, lindane, DDT, and malathion against the Schistome-bearing snail, Biomphalaria alexandria, and the mosquito, Culex pipiens fatigans. His intention was to determine if one chemical could do both jobs (killing both the snails and the mosquitoes). The results showed that one chemical could not be efficiently used against both.

This thesis is primarily concerned with the chemical control of *A. fulica*.

The most effective and widely used chemicals for the control of *A. fulica* have been metaldehyde, calcium arsenate, and a combination of metaldehyde and calcium arsenate.

Herklots (1948), in Hong Kong, recommended the solid aldehyde "meta" at one part "meta" powder with 30-50 parts dry rice bran be broadcast where *A. fulica* "is plentiful". He also recommended using a cement-lime wash containing 1% calcium arsenate applied to rocks and walls near gardens for control.

Weber (1953b), in Honolulu, Hawaii, conducted tests with chemical barriers against *A. fulica* using copper sulfate crystals, aldrin 25% dust, dieldrin 25% dust, Paris green, salt, cryolite, and parathion 1% dust. Food was placed at one end of a cage and five *A. fulica* were placed at the other end of the cage. A chemical barrier, 1/4 inch wide, was placed across the center of the floor of the cage separating the *A. fulica* from the food.

TABLE I. RESULTS OF WEBER'S (1953b) TESTS WITH CHEMICAL BARRIERS AGAINST *ACHATINA FULICA* BOWDICH.

Material	(N = 5)	
	Number of *A. fulica* crossing barrier	Number of *A. fulica* killed by barrier
copper sulfate crystals ..	2	2
copper sulfate crystals (1 inch band)	0	0
aldrin 25% dust	5	5
dieldrin 25% dust	3	1
Paris green	3	1
salt	0	1
cryolite	3	3
parathion 1% dust	2	1

Weber (1953a) also conducted tests in Honolulu to determine the effectiveness of spacing of rocks treated with a mixture of calcium arsenate, lime, and cement. His tests showed that the smaller the grid spacing of the poison-coated rocks, the greater the mortality of A. fulica (10 ft. grid, 6.8% mortality; 3.5 ft. grid, 18.4% mortality; and 1.75 ft. grid, 40% mortality).

Weber (1954) reported that a 1% penite spray and Bug-geta® pellets were used to combat A. fulica in Hawaii (penite in the rural areas and Bug-geta pellets in the populated areas).

Peterson (1957) lists sodium arsenite; metaldehyde and calcium arsenate; a poisonous whitewash of calcium arsenate 40%, slaked lime 55%, and cement 5%; wood ashes; and copper sulfate as chemicals investigated for the control of A. fulica on Guam.

Pangga (1947), in the Philippines, got satisfactory control of A. fulica using baits containing metaldehyde 5% and 10% a.i. in rice bran. Pangga (1957) also conducted barrier tests using two-inch bands of hydrated lime, tobacco dust, and salt applied on the soil surrounding 25 A. fulica. The A. fulica in the tests failed to cross the bands. In the tobacco dust barrier test, 9 of the A. fulica died after 5 days. In the salt barrier test, 18 of the A. fulica died after 36 hours. In the hydrated lime barrier test, all of the A. fulica went into aestivation.

Butler and Kim (1959), in Honolulu, Hawaii, conducted four tests to evaluate bait formulation of Ortho Bug-geta® pellets (calcium-arsenate 5%-metaldehyde 3.25%), Ortho Bug-geta® pellets (dieldrin 1%-metaldehyde 2.75%) and cinder mix (metaldehyde 3.9%) against A. fulica.

Butler and Kim concluded:

- The same amount of metaldehyde/acre in Bug-geta pellets gives a higher mortality than when in cinder mix.
- Under heavy moisture conditions, metaldehyde in Bug-geta pellets gives a higher mortality than when in cinder mix.
- Bug-geta pellets effectively kill _A. fulica_ after nine days of weathering, but cinder mix does not.
- The cinder mix attracted snails but didn't kill all those attracted.
- Bug-geta pellets containing arsenic and dieldrin were equally effective in killing _A. fulica_.

Kim (1959a), in Honolulu, Hawaii, evaluated the effectiveness of spraying metaldehyde on _A. fulica_ in dense vegetation (tall grass). Kim used metaldehyde sprays of 1%, 3%, and 6% a.i. replicated three times. The tests were started March 31, 1959, and concluded April 1, 1959. The mortality of _A. fulica_ was 10%, 36.6%, and 30% respectively. The test was probably terminated too soon to be indicative of the true mortality that might be given by the three concentrations.

Kim concluded:

- Where vegetation is dense, it is difficult to kill _A. fulica_. by "simulated aerial spraying".
- The spray residual is not effective after a rain.
- The percentage of _A. fulica_ killed is low compared to when the spray is applied directly on their bodies.

Kim (1959b) also conducted tests on the effectiveness of weathered cinder-mix pellets. Pellets broadcast at Hilo, Hawaii, March 5, 1959, were picked up on April 2, 1959, and sent to Honolulu, Hawaii. On April 7, 1959, the pellets were placed in a cage with 10 A. fulica. By April 15, 1959, 8 of the 10 A. fulica were dead.

Mead (1961) includes a chapter on chemical control of A. fulica in his book. He reviewed the literature in general on the control of economic land mollusks. He lists metaldehyde and calcium arsenate, sodium arsenite, ashes and copper sulfate, carbon disulfide, chlordane, coal tar, DDT, gammexane, hydrocyanic acid gas, kerosene emulsion, metaldehyde, methyl bromide gas, sodium chloride, and sodium dinitro-ortho cresylate, as being used or tried for the control of A. fulica.

Srivastava et al. (1968) conducted tests using 3% and 5% metaldehyde pellets against A. fulica at Port Blair, India. They concluded that the metaldehyde 5% bait was more effective than the 3% bait and mortality was greater on rainy days.

Nair et al. (1968), in India, conducted tests with metaldehyde sprays and dusts against A. fulica (with 155 mm shells). They reported that the metaldehyde 1% spray persisted in the field at a toxic level for four days.

TABLE II. RESULTS OF NAIR ET AL. (1968) TESTS WITH METALDEHYDE AGAINST *ACHATINA FULICA* BOWDICH.

Treatment	Number Snails	Percentage Mortality After (Days) 1	2	3	4	5
Laboratory trials						
metaldehyde dust 2%	25	64.0	100	----	---	---
metaldehyde spray 4%	25	92.0	100	----	---	---
metaldehyde spray 2%	25	84.0	100	----	---	---
metaldehyde spray 1%	25	80.0	100	----	---	---
metaldehyde spray 0.5% ...	25	12.0	56.0	68.0	100	---
metaldehyde spray 0.25% ..	25	16.0	56.0	56.0	56	56
control	25	0	0	0	0	0
Field cage test at Vellayani						
metaldehyde dust 2%	25	0	16.0	48.0	76	100
metaldehyde dust 1%	30	13.2	53.3	83.3	100	---
control	30	0	0	0	0	0
Field test at Palghat						
metaldehyde spray 1%	82	93.3	-----	----	---	---
control	37	0	0	0	0	0

Mitchell (personal communications, 1973), in Honolulu, Hawaii, screened naled, DDT, Zectran®, dimetilan, metaldehyde 50% WP, metaldehyde 3% bait, copper sulfate, diazinon, Supracide®, malathion, dimethoate, dicrotofos, Azodrin®, Isotox® garden spray (5% lindane, 10% malathion, 5% DDT, 3% tetradifon), endosulfan, and dimetilan sugar bait. The first test consisted of dipping *A. fulica* in the treatment solution for 15 seconds. In the second test the snails were placed on cabbage that had been treated with the test materials. The copper sulfate was screened at 2 lbs. a.i./acre, Zectran® at 0.75 lbs. a.i./acre, dimethoate at 0.5 lbs. a.i./acre, and the remaining materials at 1 lb. a.i./acre. Metaldehyde 50% WP, copper sulfate, Supracide®, and Isotox® gave mortalities of 75%, 86.25%, 75%, and 5% respectively

for the dip treatments and 44%, 12%, and 8% respectively for the foliage treatments. The metaldehyde 3% a.i. bait gave 86.25% and 76% mortalities of *A. fulica*. The remaining compounds gave lower mortalities.

Mandel and Ghose (1970), in India, conducted tests with *A. fulica* dusted with calcium arsenate to study histopathological changes and glycogen mobilization. Within 65-70 hours of application, 100% of the treated *A. fulica* died.

Roth (1971), in the United States, conducted fumigation tests with Carboxide® against *A. fulica*. He recommended a dosage of 320 mg. of Carboxide/liter for quarantine fumigation purposes. A dosage of 200 mg. of Carboxide/liter for 16 hours at 5.6, 11.2, and 22.2° C gave 100% mortality without a load in the fumigation chamber. With a load in the chamber, around 260 mg. of Carboxide/liter were needed to give 100% mortality of *A. fulica*.

II. MATERIALS AND METHODS

MATERIALS

The baits used in the screening and field tests were obtained from basic producers or formulators; formulated by the Chemicals Coordination Laboratory, Agricultural Environmental Quality Institute (formerly Pesticide Chemicals Research Branch), Agricultural Research Service, U. S. Department of Agriculture; and hand-formulated by myself.

A Dial-O-Gram scale (1600-gram capacity), manufactured by the Ohaus Scale Corporation, Florham Park, New Jersey, was used to weigh the chemicals and baits (Fig. 15).

The technical candidate molluscicides (Fig. 15) were obtained from basic pesticide manufacturers, formulators, and the Chemicals Coordination Laboratory.

The formulated candidate molluscicides (Fig. 15) were obtained from pesticide manufacturers; formulators; and Plant Protection and Quarantine Programs, Animal and Plant Health Inspection Service, USDA.

A. fulica adults with shell lengths of 50-80 mm (25.4 mm = one inch) were used in the Phases I, II, and III screening and field tests. The *A. fulica* were collected on the island of Oahu wherever sufficient numbers were available. In Honolulu, *A. fulica* were collected at the University of Hawaii Manoa Campus, Punchbowl National Cemetary, Board of Water Supply's water tank off Round Top Drive on Tantalus, Arcadia home for the retired, Tripler residential area, and from Aiea and Hawaii Kai residents. In Central Oahu, *A. fulica* were collected from Schofield Barracks and Wheeler Air Force Base (Wahiawa). In Leeward Oahu, *A. fulica* were collected from a citrus orchard in Maili (near Waianae).

On the windward side of the island, A. fulica were collected at the homes of several residents in Kailua and at a Waimanalo papaya farm.

The A. fulica used in Phase IV, regulatory treatment development tests, were reared from eggs from cultured A. fulica or were hand-collected from above mentioned Oahu sources.

A. fulica with shells of $2\frac{1}{2}$ and $3\frac{1}{2}$ whorls were arbitrarily classified as infants, $4\frac{1}{2}$ and $5\frac{1}{2}$ whorls as young, and $6\frac{1}{2}$ whorls and over as adults.

The eggs used in Phase IV were obtained from cultured A. fulica.

The soils used in Phase IV were vermiculite, sand, volconite mixed with black peat (2.7:1 by weight), topsoil mixed with black peat (1:1 by volume), and six types of soil (Comp. #1--Biscayne Gardens vic., Comp. #2--North Miami vic., Comp. #3--NW 88 Terrace vic., OPA--Opalocka vic., tomato-corn land--grey marl, and potato land--sandy, coral rock) from the Miami, Florida, area.

Figure 1.
Lateral view of the right side of adult *Achatina fulica* Bowdich.

Figure 2. Frontal view of adult *Achatina fulica* Bowdich.

Figure 3.
Lateral view of the left side of adult *Achatina fulica* Bowdich.

Figures 1-3. Lateral and frontal views of $1\frac{1}{2}$-year old *Achatina fulica* Bowdich with $8\frac{1}{2}$-whorl shell measuring 157.4 mm x 64.7 mm (6.2 x 2.55 inches).

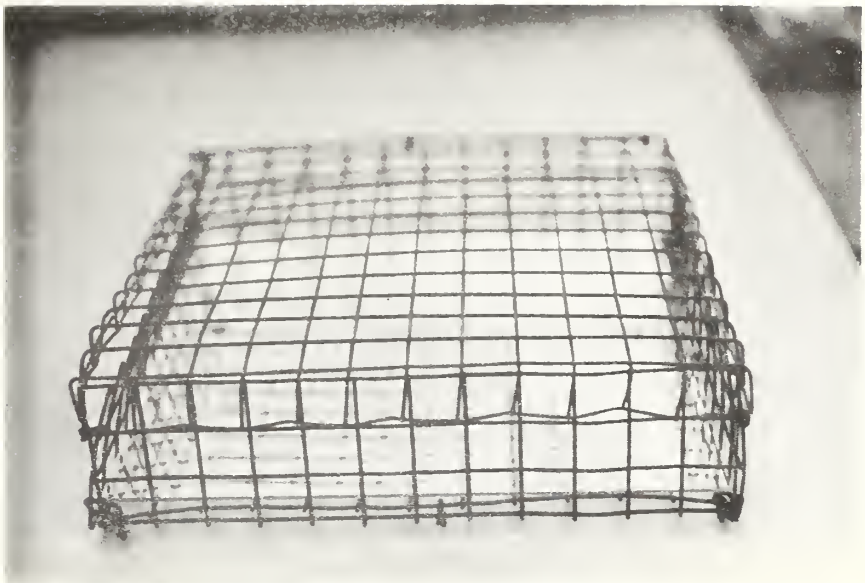

Figure 4. Screening cage: 12" x 12" x 3", 1" wire mesh with a 12" x 12" glass plate on the bottom of the cage. Used in Phases I and II, initial screening tests of technical and formulated candidate molluscicides and bait screening tests.

Figure 5. Screening cage rack: 57" long x 22" high x 12" deep with three shelves (nylon screens separating shelves), nine-cage capacity. Used in Phases I and II tests.

Figure 6. Field cage: 1' circumference, 1' high of 1" wire mesh with 1" prongs on the bottom of the cage forced into the ground, and 1" mesh poultry wire screen placed over the top of the cage to prevent Achatina fulica Bowdich adults from escaping. The cage encompasses an area of 11 sq. ft. Used in Phase III, field tests.

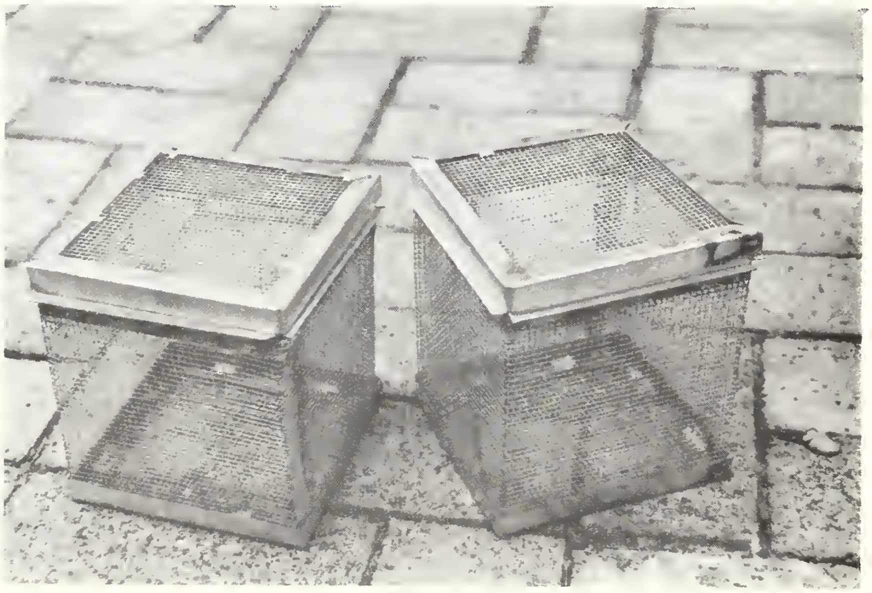

Figure 7. Screening cage (5" deep x 4" x 4", 1/8" wire mesh with cover) used for ovicidal tests against eggs of Achatina fulica Bowdich. Used in Phase IV, regulatory treatment development tests.

Figure 8. Specially constructed screening device (3' x 1', 1/8" wire mesh screen affixed to a wood frame) to facilitate separating eggs and infants of Achatina fulica Bowdich from soil. Used in Phase IV, regulatory treatment development tests.

Figure 9. Eggs of Achatina fulica Bowdich, soil clods, debris, and adult A. fulica screened from soil on egg-screening device pictured in Fig. 8.

Figure 10. Dipping tubs (165-oz. capacity, wax-coated cardboard). The quart pot (L.) and gallon pot (R.) (see Fig. 11), containing Achatina fulica Bowdich buried in soil, are immersed in treatment solution in the dipping tubs. Tubs used in Phase IV, regulatory treatment development tests.

Figure 11. Quart and gallon size nursery pots (Polycan) used in Phase IV tests.

Figure 12. 165-oz. capacity tubs filled with soil used for drench treatments of eggs, infants, and adults of Achatina fulica Bowdich buried in soil. Used in Phase IV, regulatory treatment development tests.

Figure 13. Compartmentalized plastic tray (6" x 4" x $1\frac{1}{4}$" deep overall dimensions with six 1" x 4" x $1\frac{1}{4}$" deep compartments with 5/32" holes drilled in hinged cover and bottom of the tray). Used in Phase IV tests.

Figure 14. Clear plastic shoe box ($11\frac{1}{2}$" long x 5" wide x $3\frac{1}{2}$" deep with cover--5/32" holes drilled in cover and bottom of shoe box). Used in Phase IV, regulatory treatment development (treated-foliage) tests.

Figure 15. Scale, bait formulating equipment and materials, technical and formulated compounds (only a few shown) provided by various chemical companies, and hand-formulated baits (dablets on sheet of aluminum foil) used in the screening of candidate molluscicides against *Achatina fulica* Bowdich.

METHODS

Phase I, Initial Screening Tests of Candidate Molluscicides:

At the onset of the screening program, 25 grams of 2%, 5%, and 10% a.i. solutions of candidate molluscicides were spread uniformly over 12" x 12" glass plates on the bottom of 12" x 12" x 3", 1" wire mesh cages (Fig. 4). The solutions were allowed to dry, and then six adult *A. fulica* were placed on each plate. The cages containing the *A. fulica* were held in screening cage racks (Fig. 5) and observed for one week. The mortality data were recorded at the end of the one week exposure period (Table IV). The preparation of the treatment solutions evolved to dissolving one gram of technical candidate molluscicide in 10 grams of solvent (usually acetone) and proceeding as above. The technical materials were assumed to be 90-100% pure. A dosage of 90 lbs. a.i./acre for the technical candidate molluscicides was used when the purity was unknown.

One gram of 100% pure material/sq. ft. amounts to 96 lbs. a.i./acre, and one gram of 90% pure material/sq. ft. amounts to 86.36 lbs. a.i./acre.

Ninety lbs. a.i./acre was arbitrarily used as the constant. Where formulated materials were used, they were diluted, if necessary, to make 10-gram solutions. A 10-gram solution was adequate to cover uniformly the 12" x 12" glass plate. The formulated materials were applied to the glass plates at the rate of 96 lbs. a.i./acre. Wetted paper towels were maintained in the cages for the duration of the tests. This served as a source of moisture and food for the *A. fulica* and kept them from aestivating.

Phase II, Bait Screening Tests:

Initially this phase was bypassed and promising molluscicide baits were field tested on the basis of their performance in the initial screening tests (Phase I). The bait screening phase was added to screen out those baits that had low molluscicidal action against A. fulica. This reduced the number of compounds requiring field testing.

Materials which killed five (83.3%) of the six A. fulica in the initial screening phase were made into 2%, 4%, and 8% a.i. baits.

A total of 1.56 grams of bait of each concentration was applied to the 12" x 12" glass plate on the bottom of the screening cage (Fig. 4). This is equivalent to 3, 6, and 12 lbs. a.i./acre respectively. Six A. fulica were placed in each cage. The cages containing the A. fulica were held in the screening cage racks for one week (Fig. 5). A wetted paper towel was maintained in each cage during the exposure period. At the end of the week, the percent of dead A. fulica was recorded (Table V).

Phase III, Field Tests:

At the start of the screening work, candidate molluscicides which gave a high degree of mortality of A. fulica in Phase I were directly tested (primarily as baits) in the field. Later, only those materials which killed four (66.7%) out of six adult A. fulica in Phase II were field tested as 2%, 4%, and 8% a.i. baits.

In Phases II and III, 1.56 grams of bait/sq. ft. was selected as the constant to be used for all concentrations of baits.

The field cage (Fig. 6) encompassed approximately 11 sq. ft. (11 x 1.56 = 17.16 grams of bait/field cage). Baits of 2%, 4%, and 8% a.i. were tested. A constant amount of 1.56 grams of bait/sq. ft.

(17.16 gm./cage) amounted to 3, 6, and 12 lbs. a.i./acre respectively.

Eleven A. fulica were used in each cage. Each treatment was replicated three times. The percent of dead A. fulica was recorded at the end of a two-week test period (Table VI).

Obtaining commercially prepared baits of the chemicals which qualified for the Phases II and III tests was not always possible. Therefore, many of the baits (Fig. 15) tested were formulated in the laboratory. The inert materials used for formulating the baits were Pro-Vita cereal, wheat germ, and cornstarch. (The Pro-Vita cereal is manufactured by Pro-Vita Natural Foods, 201 Myer St., Chico, Ca. 95926.) Pro-Vita cereal contains 14 grains and seeds (wheat, oat, barley, long grain rice, short grain rice, corn, millet, rye, flax seed, soya grit, sesame seed, sunflower seed, buckwheat, and alfalfa seed) and three dried fruits (raisin, fig, and date).

The Pro-Vita cereal was combined with wheat germ at 1:1, and the cereal-wheat germ mixture was combined with cornstarch at 10:1 by weight.

The candidate molluscicides were dissolved in water or acetone and then combined with the proper amount of inert ingredients in a 400 ml beaker. The combined materials were then stirred by hand, using a scoopula, until uniformly mixed. Acetone was the better solvent but nullified the tacky property of the cornstarch, therefore, water had to be added. Where water could serve as the solvent, it was combined with the inert ingredients at 1:2 by weight. This ratio gave the formulated bait the desired consistency so that "pellet" dablets could be formed. The dablets (irregular sizes) were removed from the formulated mixture by using the tip of a scoopula. The bait dablets were then placed on a piece of aluminum foil to dry (Fig. 15).

Phase IV, Regulatory Treatment Development Tests:

Materials which demonstrated molluscicidal action against A. fulica in the earlier tests, and at the same time were widely used on fruit and vegetable crops, were examined in this part of the screening of candidate molluscicides. Efforts were concentrated on developing treatments and methods that would kill all stages of A. fulica (eggs, infants, young, and active and aestivating adults). An effective regulatory treatment against A. fulica was needed so nursery stock could be moved from nurseries in the regulated areas in Miami, Florida.

The tests conducted in Phase IV consisted of ovicidal, molluscicidal, phytotoxicity-molluscicidal, and treated-foliage feeding tests.

In Ovicidal Test No. 1, eggs from two clutches laid by two cultured A. fulica, May 29, 1972, were assigned at random to twelve 4" x $1\frac{1}{4}$" x $1\frac{1}{4}$" deep compartments of two $8\frac{1}{4}$" x $4\frac{1}{4}$" x $1\frac{1}{4}$" plastic compartmentalized trays with hinged covers (Fig. 13). Holes (5/32") had been drilled in the covers and bottoms of the trays. One inch of pre-dampened sand was placed over the eggs. The treatment solutions of 0.01%, 0.05%, 0.1%, 1%, and 5% a.i. at the rate of 1.87 grams/cubic inch of soil were carefully poured from a beaker onto the sand. Control eggs took 23 days to first hatch.

In Ovicidal Test No. 2, eggs from three clutches laid June 30 and July 1, 1972, by cultured A. fulica were assigned at random to treatment plots. The eggs were buried at depths of 1, 2, 3, and 4 inches below the soil surface in specially constructed 4" x 4" x 5" deep, 1/8" wire mesh cages (Fig. 7). The cages were buried in the sand at the base of a hedgerow. Two blocks or areas, each 1' x 3' containing four cages with the eggs buried in sequence at 1-, 2-, 3-, and 4-inch depths were

treated with one gallon of 0.05% and 0.1% a.i. treatment solution/block respectively. Eggs in the control plots were buried one and four inches deep and treated with water. At the end of the test period, water was hosed through the screen cages to separate the eggs from the soil and other debris. The 1/8" wire mesh screen separated the eggs and infants of _A. fulica_ from the soil. This method facilitated obtaining the egg nonhatch and/or mortality data. Control eggs took 36-37 days to first hatch.

In Ovicidal Test No. 3, eggs from two clutches laid by cultured _A. fulica_ August 27, 1972, were buried in soil August 28, 1972, one inch below the surface in a 165-oz. capacity tub (Fig. 12) serving as the treatment plot. A third clutch of eggs laid August 28 by a cultured _A. fulica_ was buried one inch below the soil surface in a tub serving as the control plot. Both tubs contained soil to a depth of four inches. Drain holes were punched in the bottom of each tub. The 0.1% a.i. treatment solution and the control solution (water), at the rate of 4.5 grams solution/cubic inch of soil, were poured into the respective tubs onto the soil containing the eggs. At the end of the test period, the soil containing the eggs was dumped onto a specially constructed separating device consisting of a 3' x 1', 1/8" wire mesh screen stapled to a wood frame (Fig. 8). Water was hosed over the contents. The soil passed through the screen, but the eggs and infants of _A. fulica_ did not. Control eggs took 28 days to first hatch.

No specific time limit could be set for the ovicidal tests. The tests were held 10 days beyond the date first hatch occurred in the control. At the end of this period the nonhatch data was recorded

(Table VII). Lettuce was maintained in the treatment and control plots so that hatching A. fulica would have food.

The molluscicidal (Table VIII) and the phytotoxicity-molluscicidal (Table IX) tests in Phase IV consisted of applying the treatment solutions as drench and dip treatments.

The drench treatments consisted of pouring the treatment solutions into wax-coated cardboard tubs (Fig. 12) to saturate soils in which A. fulica were buried. The drench treatments consisted of 0.01%, 0.05%, 0.1%, 1%, and 5% a.i. solutions applied at the rates of 2.5, 3.5, 4, and 4.5 grams/cubic inch of soil. Aestivating and active-wild A. fulica and cultured A. fulica three weeks, one month, two months, three months, five months, and unknown months old were used. The procedure essentially was to place soil and A. fulica in a tub (Fig. 12). Then the treatment solution was poured from a one gallon metal sprinkler can into the tub onto the soil containing A. fulica. The soil types and soil pH were varied to note their effects on the treatments.

With the dip treatments, the pots containing the soil and A. fulica were immersed in the treatment solutions (Fig. 10). The size of the plant pots (Fig. 11), percent active ingredient, size and age of A. fulica used, types of plants used, and duration of exposure period were varied. Plants were used in some of the dip treatment tests to detect phytotoxicity that might be associated with some of the formulations and carriers. One A. fulica was buried among the roots of each plant in the phytotoxicity-molluscicidal tests in Phase IV. This served the dual purpose of indicating phytotoxicity and molluscicidal action.

Wax-coated, 165-oz. capacity cardboard tubs (Fig. 10) were used to hold the treatment solutions in which the plant pots containing plants and *A. fulica* were dipped.

The process used in the treated-foliage feeding tests (Table X) was to dip Manoa lettuce in a treatment solution and expose the treated lettuce to *A. fulica*. In each test as the lettuce was eaten, it was replenished with more treated lettuce. Damp sand was maintained on the floor of the cages.

In the treated-foliage feeding tests, compartmentalized plastic trays (Fig. 13) were used for the infant *A. fulica* and plastic shoeboxes for the young and adult *A. fulica* (Fig. 14).

III. RESULTS

In Tables IV, V, and VI, the rating of the candidate molluscicides (Table III) was arbitrarily set by assigning a rating of 0-6 based on the percent of *A. fulica* killed in a test.

A rating of "6" was given to a molluscicide if 100% of six *A. fulica* were killed in a screening test and 75% of 33 *A. fulica* were killed in a field test. For baits applied at 6 and 12 lbs. a.i./acre giving mortality comparable to the standard, the rating was reduced one number.

The dosages of 90 lbs. a.i./acre for the contact screening and 3 lbs. a.i./acre for the bait screening and field tests were arbitrarily used as the standards for rating the molluscicides.

TABLE III. RATING LEDGER OF CANDIDATE MOLLUSCICIDES IN PHASES I, II, AND III TESTS.

MOLLUSCICIDE RATING	PERCENT *A. FULICA* MORTALITY		DOSAGE Number lbs. a.i./acre		
	N = 6 Screening Tests	N = 33 Field Tests	Screening Tests Contact	Screening Tests Bait	Field Tests
6 -- very good	100	75	90	3	3
	53	50	48	2	2
	21	25	19	1	1
5 -- good	83	62	90	3	3
	44	41	48	2	2
	17	20	19	1	1
4 -- moderate	66	50	90	3	3
	35	33	48	2	2
	14	16	19	1	1
3 -- light	50	37	90	3	3
	22	25	48	2	2
	10	12	19	1	1
2 -- slight	33	25	90	3	3
	17	16	48	2	2
	7	8	19	1	1
1 -- trace	16	12	90	3	3
	8	8	48	2	2
	3	4	19	1	1
0 -- non	0-15	0-11	90	3	3
	0-7	0-7	48	2	2
	0-2	0-3	19	1	1

Phase I, Initial Screening Tests:

TABLE IV. RESULTS OF SCREENING TECHNICAL AND FORMULATED CANDIDATE MOLLUSCICIDES AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
Carbamate Compounds:					
1.	ENT-988	ziram	0	90	0
2.	ENT-17588	Pyrolan®	83.3	90	5
3.	ENT-17957	coumaphos	0	90	0
4.	ENT-19060	Isolan®	100	90	6
5.	ENT-23969	carbaryl	83.3	48	6
		....	50.0	19	6
6.	ENT-25500	Hercules 5727[a]	100	90	6
7.	ENT-25726	Mesurol®	100	240	6
		....	100	120	6
		....	100	48	6
8.	ENT-25736	carbanolate	66.7	90	4
9.	ENT-25766	Zectran®	100	240	6
		....	100	120	6
		....	83.3	48	6
10.	ENT-25784	aminocarb[a]	100	90	6
		....	100	48	6
11.	ENT-25843	Shell SD-8530	100	90	6
		......	100	48	6
12.	ENT-25911	Hercules 9326	0	90	0
13.	ENT-27102	Shell SD-9098	100	90	6
		......	100	48	6
14.	ENT-27127	Bux®	50.0	90	3
15.	ENT-27128	Chevron Ortho® 5655[a]	83.3	90	5
16.	ENT-27164	carbofuran	100	90	6

TABLE IV. (CONTINUED) RESULTS OF SCREENING TECHNICAL AND FORMULATED CANDIDATE MOLLUSCICIDES AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long)		
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Carbamate Compounds:					
17.	ENT-27213	Bay 38799	16.7	90	1
18.	ENT-27300	promecarb	83.3	90	5
19.	ENT-27334	Hercules 9007	50.0	90	3
20.	ENT-27341	methomyl	See Phases II & III tests		
21.	ENT-27382	Niagara NIA-10559 ...	33.3	90	2
22.	ENT-27389	dioxacarb	100	90	6
23.	ENT-27392	Union Carbide UC-30044[a]	100	90	6
24.	ENT-27393	Union Carbide UC-30045[a]	100	90	6
25.	ENT-27410	Ciba C-10015	100	90	6
26.	ENT-27438	fenazaflor	66.7	90	4
27.	ENT-27454	Hercules 9418	50.0	90	3
28.	ENT-27466	Bay 42688[a]	100	90	6
29.	ENT-27519	Shell SD-16898[a]	83.3	90	5
30.	ENT-27524	Bay 85032	0	90	0
31.	ENT-27550	Velsicol VCS-348 ...	16.7	90	1
32.	ENT-27553	Shell SD-15289[a]	100	90	6
33.	ENT-27557	Ciba C-11753	100	90	6
34.	ENT-27564	Ciba C-9643	100	90	6
35.	ENT-27566	formetanate hydrochloride	100	90	6

TABLE IV. (CONTINUED) RESULTS OF SCREENING TECHNICAL AND FORMULATED CANDIDATE MOLLUSCICIDES AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long)		
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Carbamate Compounds:					
36.	ENT-27568	Bay 78389[a]	100	90	6
37.	ENT-27613	Shell SD-17250[a]	100	90	6
		.....	100	48	6
		.....	100	19	6
38.	ENT-27649	Intl. Minerals and Chemicals, Inc. IMC-48003	100	90	6
39.	ENT-27655	Shell SD-17578[a]	100	90	6
40.	ENT-27660	3M Co. MBR-5667[a]	100	90	6
41.	ENT-27695	Fisons NC-6897	100	90	6
42.	ENT-27696	3M Co. MBR-6168[a]	100	90	6
43.	ENT-27704-X	Chevron RE-11775[a] ...	100	90	6
		...	0	10	NR
44.	ENT-27705-X	Chevron RE-11776[a] ...	100	90	6
45.	ENT-27766-X	pirimicarb	100	90	6
46.	ENT-51843	Shell SD-9396	0	48	0
		......	0	19	0
Organic Phosphate Compounds:					
47.1.	ENT-20738	dichlorvos	33.3	90	2
48.2.	ENT-23284	ronnel	0	96	0
49.3.	ENT-23437	disulfoton	100	90	6
50.4.	ENT-24042	phorate	100	90	6
51.5.	ENT-25602	crufomate	16.7	96	1

TABLE IV. (CONTINUED) RESULTS OF SCREENING TECHNICAL AND FORMULATED CANDIDATE MOLLUSCICIDES AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Organic Phosphate Compounds:					
52.6.	ENT-25841	Gardona®	See Phase II tests		
53.7.	ENT-27129	Azodrin® (56% a.i. EC)	100	96	6
54.8.	ENT-27163	phosalone	50	90	3
55.9	ENT-27165	Abate®	See Phase II tests		
56.10.	ENT-27311	chlorpyrifos	16.7	96	1
57.11.	ENT-27396	Chevron Ortho® 9006	50.0	10	6
58.12.	ENT-27506	Stauffer R-14487 ...	0	90	0
59.13.	ENT-27508	Stauffer R-14493[a] ...	83.3	90	5
60.14.	ENT-27520	Dowco(R) 214	83.3	96	5
61.15.	ENT-27542	Stauffer R-14805 ...	33.3	90	2
62.16.	ENT-27543	Stauffer R-14855 ...	0	90	0
63.17.	ENT-27544	Stauffer R-15201[a] ...	83.3	90	5
64.18.	ENT-27549	Stauffer R-15022[a] ...	100	90	6
65.19.	ENT-27647	Stauffer R-15996[a] ...	100	90	6
66.20.	ENT-27648	Stauffer R-14789 ...	50.0	90	3
67.21.	ENT-27664	Stauffer R-15206[a] ...	100	90	6
68.22.	ENT-27665	Stauffer R-16745[a] ...	83.3	90	5
69.23.	ENT-27666	Stauffer R-15644[a] ...	100	90	6

TABLE IV. (CONTINUED) RESULTS OF SCREENING TECHNICAL AND FORMULATED CANDIDATE MOLLUSCICIDES AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long)		
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
Salicylanilide Compounds:					
70.1.	ENT-8114	2-hydroxy-N-phenylbenzamide	16.7	240	0
71.2.	ENT-25516	3,4',5-tribromo-salicylanilide	100	90	6
72.3.	ENT-27139	4',4",5-trichloro-2-hydroxy-3-biphenyl-carboxanilide	0	90	0
73.4.	ENT-50091	5-chlorosalicylanilide	0	90	0
74.5.	ENT-50101	4',5-dichloro-salicylanilide	0	90	0
75.6.	ENT-50102	3',5-dichloro-salicylanilide	0	90	0
76.7.	ENT-50922	4'-chloro-3-nitro-*o*-salicylotoluidide (Ben Venue 4C2M(B)P5)[a]	100	90	6
77.8.	ENT-50925	5'-chloro-3-nitro-*o*-salicylanisidide	0	90	0
78.9.	ENT-50927	4',5-dibromo-3-nitrosalicylanilide	33.3	90	2
79.10.	ENT-50930	5'-methyl-3-nitro-*o*-salicylanisidide	16.7	90	1
80.11.	ENT-50933	3'-chloro-5-nitrosalicylanilide	33.3	90	2
81.12.	ENT-51385	2',4'-dichloro-3-nitrosalicylanilide (Ben Venue BVL VI-18)[a]	100	90	6
82.13.	ENT-51387	3'-chloro-5-bromo-3-nitrosalicylanilide	0	90	0

TABLE IV. (CONTINUED) RESULTS OF SCREENING TECHNICAL AND FORMULATED CANDIDATE MOLLUSCICIDES AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long)		
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Salicylanilide Compounds:					
83.14.	ENT-51396	4',4'''-sulfonylbis (3-nitrosalicylanilide)	0	90	0
84.15.	ENT-51397	Ben Venue BVL VI-13b	16.7	90	1
85.16.	ENT-51403	2'-ethyl-3-nitrosalicylanilide	16.7	90	1
86.17.	ENT-51404	2',4',6'-tribromo-3-nitrosalicylanilide (Ben Venue BVL 246-NBS-47)	83.3	90	5
87.18.	ENT-51805	3-nitro-3',4'-salicyloxylidide	33.3	90	2
88.19.	ENT-51807	5-bromo-3-nitro-4'-(phenylazo) salicylanilide	0	90	0
Tin Compounds:					
89.1.	ENT-24979	tributyl tin oxide (TBTO)	83.3	90	5
90.2.	ENT-25208	triphenyl tin acetate	83.3	90	5
91.3.	ENT-27395	tricychlohexyltin hydroxide	16.7	96	1
92.4.	ENT-27428	Pennwalt TD-5032	100	90	6
93.5.	ENT-27738	Shell SD-14114	See Phase III tests		
94.6.	ENT-28009	triphenyl tin hydroxide	50.0	90	3

TABLE IV. (CONTINUED) RESULTS OF SCREENING TECHNICAL AND FORMULATED CANDIDATE MOLLUSCICIDES AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
Miscellaneous Compounds:					
95.1.	ENT-154	dinitrocresol	16.7	90	1
96.2.	ENT-1122	dinitrobutylphenol 95.6% technical	100	91	6
97.3.	ENT-1501	sodium fluosilicate	See Phase III tests		
98.4.	ENT-1773	methylene chloride ..	See Phases II & IV tests		
99.5.	ENT-8197	xylene	See Phase IV tests		
100.6.	ENT-15376	metaldehyde	See Phases II, III, IV tests		
101.7.	ENT-27446	Monsanto MON-057	0	19	0
102.8.	ENT-27474	resmethrin	0	24	0
		....	0	10	0
103.9.	ENT-31167	acetaldehyde	0	96	0
104.10.	ENT-50518	Actamer®	0	90	0
105.11.	ENT-51805	a carbanilide	0	90	0
106.12.	no ENT #	PolyTrap (a plant protectant; anti-transpirant)	See Phase IV tests		
107.13.	no ENT #	Styrid®-Caricide® (styrlpridinium chlorid 5%-diethylcarbamazine 3% (8% a.i.)	See Phase II tests		

[a] Material no longer available or development as a molluscicide not being considered by the manufacturer.

Phase II, Bait Screening Tests:

After a period of trial and error, it was necessary to record the "degree of feeding" on the baits by _A. fulica_. A rating of 0-3 was assigned:

0 = No noticeable feeding

1 = Partial feeding

2 = Moderate feeding

3 = Complete feeding (all of the bait was eaten)

The first candidate molluscicide baits tested were not given a "degree of feeding" rating. These are marked "NR" (not rated).

It was just as important to learn that a bait is not effective because it is rejected (not fed on) by _A. fulica_, as it is to learn that it is not effective because it is not toxic to _A. fulica_.

The same method was used for rating the effectiveness of the baits that were used in Phase I (Table III).

TABLE V. RESULTS OF SCREENING CANDIDATE MOLLUSCICDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
Carbamate Compounds:						
1.	ENT-17588	Pyrolan®[a]				
		2%	16.7	3	1	3
		4%	16.7	6	0	1
		8%	16.7	12	0	1
2.	ENT-19060	Isolan®				
		2%[b]	66.7	3	4	NR
		2%[a]	33.3	3	2	1
		4%[a]	0	6	0	0
		8%[a]	33.3	12	1	1
3.	ENT-23969	carbaryl[c]				
		2%	0	3	0	NR
		4%	0	6	0	NR
		8%	0	12	0	NR
4.	ENT-25500	Hercules 5727				
		2%[b]	83.3	3	5	NR
		2%[a]	33.3	3	2	3
		4%[a]	50.0	6	2	3
		8%[a]	33.3	12	1	1
5.	ENT-25726	Mesurol®[c]				
		2%	16.7	2	2	NR
		2%	0	1	0	NR
		2%	16.7	.5	3	NR
		Mesurol 2%[c] w/beer added	83.3	4	4	NR
		Mesurol 2%[c] w/beer added	83.3	2	6	NR
		Mesurol 2%[c] w/beer added	0	1	0	NR
		Mesurol 2%[c]-metaldehyde 1%	50.0	4	2	NR

TABLE V. (CONTINUED) RESULTS OF SCREENING CANDIDATE MOLLUSCICIDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

		Chemicals (Osborne, 1971)	N = 6 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
(Continued)	Carbamate Compounds:					
		Mesurol 2%[c]-metaldehyde 1%	66.7	2	5	NR
		Mesurol 2%[c]-metaldehyde 1%	0	1	0	NR
		Mesurol 2%[c] metaldehyde 4%	50.0	3	3	NR
		Mesurol 4%[c] w/beer added	100	3	6	NR
		Mesurol 4%[c]-metaldehyde 1%	100	3	6	NR
		Mesurol 4%[c]-metaldehyde 2%	83.3	3	5	2
6.	ENT-25736	carbanolate[c]				
		2%	0	3	0	3
		4%	16.7	6	0	3
		8%	0	12	0	3
7.	ENT-25766	Zectran® 2%[a]	16.7	3	1	NR
		2%[c]	0	3	0	0
		4%[c]	0	6	0	0
		8%[c]	0	12	0	0
8.	ENT-25784	aminocarb[c] 2%	16.7	3	1	3
		4%	16.7	6	0	1
		8%	33.3	12	0	1
9.	ENT-25843	Shell SD-8530[c]				
		2%	100	3	6	2
		4%	100	6	6	2
		8%	100	12	6	2
10.	ENT-27012	Shell SD-9098[c]				
		2%	0	3	0	2
		4%	0	6	0	3
		8%	0	12	0	3

TABLE V. (CONTINUED) RESULTS OF SCREENING CANDIDATE MOLLUSCICIDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)				N = 6 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
(Continued) Carbamate Compounds:							
11.	ENT-27164	carbofuran[c]					
			2%	100	3	6	NR
			2%	100	3	6	NR
			4%	0	3	0	NR
			4%	16.7	3	1	NR
12.	ENT-27341	methomyl[c]	2%	100	Unknown	6	NR
			2%	100	4	6	NR
			2%	100	2	6	NR
			2%	100	1	6	NR
			2%	83.3	.5	6	NR
13.	ENT-27389	dioxacarb[a]	2%	0	3	0	1
			4%	16.7	6	0	1
			8%	50.0	12	1	1
14.	ENT-27392	Union Carbide UC-30044[d]	2%[b]	100	3	6	NR
			2%[a]	16.7	3	1	3
			4%[a]	50.0	6	2	2
			8%[a]	16.7	12	0	1
15.	ENT-27393	Union Carbide UC-30045[d]	2%[b]	100	3	6	NR
			2%[a]	100	3	6	1
			4%[a]	100	6	6	2
			8%[a]	100	12	6	1
16.	ENT-27410	Ciba C-10015					
			2%[b]	66.7	3	4	NR
			2%[a]	33.3	3	2	3
			4%[a]	66.7	6	3	3
			8%[a]	33.3	12	1	1
17.	ENT-27438	fenazaflor[a]					
			2%	0	3	0	0
			4%	50.0	6	2	1
			8%	0	12	0	0

TABLE V. (CONTINUED) RESULTS OF SCREENING CANDIDATE MOLLUSCICIDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long)			
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
(Continued) Carbamate Compounds:						
18.	ENT-27553	Shell SD-15289				
		2%[b]	33.3	3	2	NR
19.	ENT-27557	Ciba C-11753[a]				
		2%	16.7	3	1	2
		4%	0	6	0	3
		8%	0	12	0	0
20.	ENT-27564	Ciba C-9643				
		2%[b]	100	3	6	NR
21.	ENT-27566	formetanate hydrochloride				
		2%[b]	100	3	6	NR
		2%[a]	33.3	3	2	1
		4%[a]	100	6	6	1
		8%[a]	83.3	12	4	1
22.	ENT-27568	Bay 78389[d] 2%[b]	100	3	6	NR
		2%[a]	16.7	3	2	1
		4%[a]	33.3	6	2	1
		8%[a]	66.7	12	2	2
23.	ENT-27613	Shell SD-17250[d]				
		2%[b]	83.3	3	5	NR
24.	ENT-27649	Intl. Minerals & Chemicals, Inc.				
		IMC-48003[a] 2%	0	3	0	3
		4%	0	6	0	3
		8%	0	12	0	1
25.	ENT-27655	Shell SD-17578[d]				
		2%[b]	100	3	6	NR
26.	ENT-27704-X	Chevron RE-11775[d] 2%[a]	0	3	0	1
		4%[a]	0	6	0	1
		8%[a]	0	12	0	1

TABLE V. (CONTINUED) RESULTS OF SCREENING CANDIDATE MOLLUSCICIDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)	N = 6 *A. fulica* (with shells 50-80 mm long)			
	Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
(Continued) Carbamate Compounds:				
27. ENT-27766-X pirimicarb[a]				
2%	0	3	0	3
4%	0	6	0	3
8%	0	12	0	2
Organic Phosphate Compounds:				
28.1. ENT-23437 disulfoton[a]				
2%	33.3	3	2	2
4%	16.7	6	0	1
8%	66.7	12	3	1
29.2. ENT-24042 phorate 2%[b] ..	100	3	6	NR
2%[a] ..	0	3	0	3
4%[a] ..	0	6	0	0
8%[a] ..	0	12	0	2
30.3. ENT-25841 Gardona® [c]				
2%	0	3	0	3
2%	0	3	0	3
31.4. ENT-27129 Azodrin® [a]				
2%	50.0	3	3	2
4%	16.7	6	0	1
8%	16.7	12	0	1
32.5. ENT-27165 Abate® 2%[c]	16.7	3	1	NR
33.6. ENT-27311 chlorpyrifos[c]				
2%	83.3	3	5	NR
2%	50.0	3	3	NR
34.7. ENT-27396 Chevron Ortho® 9006[a] 2%	33.3	3	2	2
4%	83.3	6	4	1
8%	50.0	12	2	2
35.8. ENT-27542 Stauffer R-14805 4%[a]	0	6	0	3

TABLE V. (CONTINUED) RESULTS OF SCREENING CANDIDATE MOLLUSCICIDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
(Cont.) Organic Phosphate Compounds:						
36.9.	ENT-27544	Stauffer R-15201[d] 2%[a] ..	0	3	0	3
		4%[a] ..	0	6	0	3
		8%[a] ..	0	12	0	3
37.10.	ENT-27647	Stauffer R-15996[d] 2%[a] ..	0	3	0	3
		4%[a] ..	0	6	0	0
		8%[a] ..	0	12	0	1
38.11.	ENT-27664	Stauffer R-15206[d] 2%[a] ..	16.7	3	1	3
		4%[a] ..	0	6	0	0
		8%[a] ..	0	12	0	1
39.12.	ENT-27665	Stauffer R-16745[d] 2%[a] ..	16.7	3	1	1
		4%[a] ..	16.7	6	0	3
		8%[a] ..	0	12	0	1
Salicylanilide Compounds:						
40.1.	ENT-25516	3,4',5-tribromo=salicylanilide				
		2%[b]	83.3	3	5	NR
		2%[a]	0	3	0	0
		4%[a]	0	6	0	0
		8%[a]	0	12	0	0
41.2.	ENT-51404	2',4',6'-tribromo-3-nitrosalicyl=anilide[a] 2% ..	0	3	0	0
		4% ..	0	6	0	0
		8% ..	16.7	12	0	1

TABLE V. (CONTINUED) RESULTS OF SCREENING CANDIDATE MOLLUSCICIDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 6 *A. fulica* (with shells 50-80 mm long)			
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
Tin Compounds:						
42.1.	ENT-24979	tributyl tin oxide[a] 2%	0	3	0	0
		4%	0	6	0	0
		8%	0	12	0	0
43.2.	ENT-25208	triphenyl tin acetate[a] 2% ..	50.0	3	3	1
		4% ..	83.3	6	4	1
		8% ..	50.0	12	2	1
44.3.	ENT-28009	triphenyl tin hydroxide 47.5% WP[a] 2%	33.3	3	2	1
		4%	83.3	6	4	1
		8%	33.3	12	1	1
Miscellaneous Compounds:						
45.1.	ENT-1122	dinitrobutyl-phenol[a] 2% ...	0	3	0	2
		4% ...	50.0	6	2	1
		8% ...	100	12	6	1
46.2.	ENT-1773	methylene chloride 5%[a]	0	100	0	2
47.3.	ENT-15376	metaldehyde:				
		Bug-geta® (metaldehyde 3.25%-calcium arsenate 5%)[c]	83.3	3	5	NR
		Bug-geta®	100	3	6	NR
		Bug-geta equivalent[b]	33.3	3	2	NR

TABLE V. (CONTINUED) RESULTS OF SCREENING CANDIDATE MOLLUSCICIDE BAITS AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)	N = 6 *A. fulica* (with shells 50-80 mm long)			
	Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6	Degree of Feeding 0-3
(Cont.) Miscellaneous Compounds:				
metaldehyde 3.9% cinder pellet[e]	100	10	6	NR
48.4. no ENT # Styrid®-Caracide® (styrlpridinium chlorid 5%-diethylcarbamazine 3% (8% a.i.)				
2%[a]	0	3	0	1
4%[a]	0	6	0	0
4%[a]	0	6	0	1

[a] Bait hand-formulated by F. J. Olson.

[b] Bait formulated by Chemicals Coordination Laboratory, Agricultural Environmental Quality Institute (formerly Pesticide Chemicals Research Branch), Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Maryland.

[c] Bait formulated by chemical company.

[d] Material no longer available or development as a molluscicide not being considered by the manufacturer.

[e] Bait formulated by the Entomology Branch, Plant Industry Division, Hawaii State Department of Agriculture, Honolulu, Hawaii.

Phase III, Field Tests:

Those baits that gave 66.6% mortality of *A. fulica* in the Phase II tests were field tested in the Phase III tests. However, in most cases, only the most effective concentration (2%, 4%, or 8% a.i.) of the baits was field tested. Some baits that gave variable mortality in the Phase II tests, e.g., formetanate hydrochloride, were field tested at the three levels of active ingredient (2%, 4%, and 8%).

Those baits that gave 100% mortality at all three concentrations in the Phase II tests were field tested only as a 2% a.i. bait, e.g. Union Carbide UC-30045. Some baits that didn't kill any *A. fulica* in the Phase II tests, because the baits were not eaten, were included in the field tests to see if under field conditions *A. fulica* would accept the baits, e.g., tributyl tin oxide.

The rating method outlined in Table III was used in the rating the effectiveness of the field tested baits.

TABLE VI. RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 33 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
Carbamate Compounds:					
1.	ENT-19060	Isolan® 2% flake bait[a]	12.1	3	1
2.	ENT-23969	carbaryl pellet baits[a] 2%	3.0	3	0
		4%	9.1	6	0
		8%	9.1	12	0
		carbaryl 4%-metaldehyde 0.5% pellet bait[b]	12.1	3	1
		carbaryl 4%-metaldehyde 0.5% pellet bait[b] with gypsum 5% added	21.2	3	1
		carbaryl 4%-metaldehyde 1% pellet bait[b] w/lime 5% added	48.5	3	3
		carbaryl 4%-metaldehyde 1% pellet bait[b]	42.4	3	3
		carbaryl 4%-metaldehyde 3% pellet bait[b] w/gypsum 5% added	87.9	3	6
		carbaryl 4%-metaldehyde 1% pellet bait[a]	27.3	3	2
		carbaryl 4% drench ...	54.4	80	NR
3.	ENT-25500	Hercules 5727 2% flake bait[a]	3.0	3	0
		4% bait[c]	18.2	6	1

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 33 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Carbamate Compounds:					
4.	ENT-25726	Mesurol® drenches			
		0.025%	0	1	NR
		0.05%	0	2	NR
		0.075%	0	3	NR
		0.1%	2.1	4	NR
		Mesurol 2% bait[b]	15.2	3	1
		Mesurol 4% flake bait[b] with beer added	6.1	3	0
		Mesurol 4% pellet bait[b]	6.1	3	0
5.	ENT-25766	Zectran® 0.075% drench	15.2	3	NR
6.	ENT-25843	Shell SD-8530 bait[b]			
		2%	42.4	3	3
		2%	24.2	3	1
		2%	21.2	3	1
		4%	39.4	6	2
		8%	39.4	12	2
7.	ENT-27102	Shell SD-9098			
		0.075% drench	3.0	3	NR
		2% pellet bait[b]	9.1	3	0
		2% pellet bait[b]	6.1	3	0
8.	ENT-27164	carbofuran 2% apple pomace pellet bait[b] ..	72.7	3	5
		carbofuran 2% apple pomace pellet bait[b] ..	18.2	3	1
		carbofuran 2% apple pomace pellet bait[a] with gypsum 5% added	24.2	3	1

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 33 *A. fulica* (with shells 50-80 mm long)		
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Carbamate Compounds:					
		carbofuran 4% apple pomace pellet bait[b]	63.6	3	5
9.	ENT-27341	methomyl 2% flake bait[b]	9.1	3	0
		2% flake bait[b] with beer added	6.1	3	0
		2% pellet bait[b]	12.1	3	1
		2% pellet bait[b]	3.0	3	0
		2% pellet bait[b]	42.4	3	3
		2% pellet bait[b] with gypsum 5% added	6.1	3	0
		2% pellet bait[b] with gypsum 5% added	75.8	3	6
		2% pellet bait[b] with lime 5% added	27.3	3	2
		2% pellet bait[b] with lime 5% added	21.2	3	1
		methomyl 1.5%-metaldehyde 0.5% pellet bait[b]	48.5	3	3
		methomyl 1.5%-metaldehyde 0.5% pellet bait[b]	54.5	3	4
		methomyl 2%-metaldehyde 0.5% pellet bait[b] with lime 5% added	36.4	3	3

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST ACHATINA FULICA BOWDICH.

Chemicals (Osborne, 1971)			N = 33 A. fulica (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Carbamate Compounds:					
10.	ENT-27392	Union Carbide UC-30044 4% bait[c] ...	36.4	6	2
11.	ENT-27393	Union Carbide UC-30045[d] 2% bait[c] ...	84.8	3	6
12.	ENT-27410	Ciba C-10015 4% bait[c]	27.3	6	1
13.	ENT-27438	fenazaflor 4% bait[c] ..	18.2	6	1
14.	ENT-27553	Shell SD-15289[d] 2% pellet bait[a]	15.2	3	1
15.	ENT-27566	formetanate hydrochloride			
		2% flake bait[a]	6.1	3	0
		2% bait[c]	33.3	3	2
		4% bait[c]	45.5	6	3
		8% bait[c]	36.4	12	2
16.	ENT-27568	Bay 78389[d] 8% bait[c] ..	21.2	12	1
17.	ENT-27613	Shell SD-17250[d] pellet baits 0.5%	39.0	2	4
		0.5%	39.0	1	6
		2%	97.0	3	6
		2%	97.0	3	6
		2%	91.0	3	6
		2%	70.0	3	6
		2%	82.0	2	6
18.	ENT-27649	Intl. Minerals and Chemicals, Inc. IMC-48003 (Kumiai TCI-65)[b]			
		2% pellet bait	0	3	0
		4% pellet bait	0	3	0

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 33 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Carbamate Compounds:					
		Intl. Minerals and Chemicals, Inc. IMC-48003 2%[b]-metaldehyde 3% pellet bait	33.3	3	2
		Intl. Minerals and Chemicals, Inc. IMC-48003 4%[b]-metaldehyde 3% pellet bait	42.4	3	3
19.	ENT-27655	Shell SD-17578[d] 2% pellet bait	27.3	3	2
20.	ENT-27696	3M Co. MBR-5667[d] 2% granular contact fumigant	12.1	3	1[e]
21.	ENT-27766-X	pirimicarb[b] pellet baits 2%	36.4	3	2
		4%	12.1	3	1
Organic Phosphate Compounds:					
22.1.	ENT-23437	disulfoton 4% bait[c]	24.2	6	1
23.2.	ENT-24042	phorate 2% flake bait[a]	3.0	3	0
24.3.	ENT-27129	Azodrin® 2% bait[c]	18.2	3	1
25.4.	ENT-27311	chlorpyrifos 2% pellet bait[b]	12.1	3	1
26.5.	ENT-27396	Chevron Ortho® 9006 2% bait[c]	42.4	3	3
		4% bait[c]	63.6	6	4

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)			N = 33 *A. fulica* (with shells 50-80 mm long)		
			Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Cont.) Organic Phosphate Compounds:					
27.6.	ENT-27549	Stauffer R-15022[b] 2%-metaldehyde 2.6% pellet bait	63.6	3	5
28.7.	ENT-27647	Stauffer R-15996[b] 2%-metaldehyde 2.6% pellet bait	36.4	3	3
29.8.	ENT-27664	Stauffer R-15206[b] 2%-metaldehyde 2.6% pellet bait	63.6	3	5
30.9.	ENT-27666	Stauffer R-15644[b] 2%-metaldehyde 2.6% pellet bait	39.4	3	3
Salicylanilide Compounds:					
31.1.	ENT-25516	3,4',5-tribromo-salicylanilide			
		2% flake bait[a]	0	3	0
		4% bait[c]	36.4	6	2
32.2.	ENT-51404	2',4',6'-tribromo-3-nitrosalicylanilide (Ben Venue BVL 246-NBS-47) 4% bait[c]	12.1	6	0
Tin Compounds:					
33.1.	ENT-24979	tributyl tin oxide 4% bait[c]	9.1	6	0[f]
34.2.	ENT-25208	triphenyl tin acetate			
		2% bait[c]	60.6	3	4
		4% bait[c]	75.8	6	5

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST ACHATINA FULICA BOWDICH.

Chemicals (Osborne, 1971)			N = 33 A. fulica (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Continued) Tin Compounds:					
35.3.	ENT-27428	Pennwalt TD-5032[b] (hexamelthylditin) flake baits 0.5%	24.2	0.75	6
		1%	54.5	1.5	6
		2%	75.8	3	6
		2%	60.6	3	5
		Pennwalt TD-5032[b] 2% bait with builders' lime 5% added	84.8	3	6
36.4.	ENT-27738	Shell SD-14114[b] 2% pellet bait	3.0	3	0
37.5.	ENT-28009	triphenyl tin hydroxide[c]			
		2% bait	63.6	3	5
		4% bait	87.9	6	6
		8% bait	97.0	12	6
Miscellaneous Compounds:					
38.1.	ENT-1112	dinitrobutylphenol			
		4% bait[c]	24.2	6	1
		8% bait[c]	9.1	12	0
39.2.	ENT-1501	sodium fluosilicate[b] 3.03%-metaldehyde 3% apple pomace pellet bait	27.3	3	2[e]
40.3.	ENT-15376	metaldehyde:			
		Bug-geta®[b] (metaldehyde 3.25%-calcium arsenate 5%) pellet bait	81.8	3	6
		....	63.6	3	5
		....	48.5	3	4
		....	93.9	6	6

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemicals (Osborne, 1971)	N = 33 *A. fulica* (with shells 50-80 mm long) Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Cont.) Miscellaneous Compounds:			
(Cont.) metaldehyde:			
Bug-geta®[b]	84.8	9	6
....	72.7	10.5	5
Bug-geta equivalent[b] pellet bait	81.8	3	6
....	93.9	6	6
....	66.7	9	5
Bug-geta equivalent[a] pellet bait	51.5	3	4
metaldehyde pellet baits[b] 3%	72.7	3	5
2.75%	57.6	3	4
2.75%	36.4	3	3
2.6%	54.5	3	4
metaldehyde 3.9% cinder pellet bait[g] ..	6.1	3	0[e]
metaldehyde 3.25% granules[b]	3.0	3	0
metaldehyde 2.75% flake bait[b]	42.4	3	0
....	24.2	3	2
metaldehyde 2.75% pellet bait[b] with gypsum 5% added	84.8	3	6
.....	63.6	3	5
metaldehyde 2.75% pellet bait[b] with lime 5% added	57.6	3	4

TABLE VI. (CONTINUED) RESULTS OF FIELD TESTS OF CANDIDATE MOLLUSCICIDES (MOSTLY BAITS) AGAINST <u>ACHATINA</u> <u>FULICA</u> BOWDICH.

Chemicals (Osborne, 1971)	N = 33 *A. fulica* (with shells 50-80 mm long)		
	Percent Mortality	Dosage lbs. a.i. per acre	Rating 0-6
(Cont.) Miscellaneous Compounds:			
metaldehyde 2.75% pellet bait[b] with calcium propionate 5% added	48.5	3	3
metaldehyde 4% pellet bait[b]	18.2	3	1
....	54.5	6	2

[a] Bait formulated by the Chemicals Coordination Laboratory, Agricultural Environmental Quality Institute (formerly Pesticide Chemicals Research Branch), Agricultural Research Service, U. S. Dept. of Agriculture, Beltsville, Maryland.

[b] Bait formulated by chemical company.

[c] Bait hand-formulated by F. J. Olson.

[d] Material no longer available or development as a molluscicide not being considered by the manufacturer.

[e] One week exposure.

[f] Data from one cage only.

[g] Bait formulated by the Entomology Branch, Plant Industry Division, Hawaii State Department of Agriculture, Honolulu, Hawaii.

Phase IV, Regulatory Treatment Development Tests:

TABLE VII. RESULTS OF OVICIDAL TESTS (CONSISTING OF DRENCH TREATMENTS) AGAINST THE EGGS OF *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	N	Inches (Depth)	Percent Mortality and/or Nonhatch	Dosage
Metaldehyde 25% EC[a]				
0.01%	24	1	25.0	1.87 grams of treatment solution per cubic inch of soil (damp sand)
0.05%	24	1	16.2	
0.1%	24	1	41.7	
1%	24	1	50.0	
5%	24	1	87.5	
Control (water) ..	24	1	25.0	
carbaryl[b]				
0.01%	24	1	75.0	1.87 grams of treatment solution per cubic inch of soil (damp sand)
0.05%	24	1	100	
0.1%	24	1	100	
1%	24	1	100	
5%	24	1	100	
Control (water) ..	24	1	54.2	
0.05%	41	1	100	2.18 grams of treatment solution per cubic inch of soil (damp sand)
0.05%	41	2	97.6	
0.05%	41	3	82.9	
0.05%	41	4	100	
0.1%	41	1	100	
0.1%	41	2	100	
0.1%	41	3	100	
0.1%	41	4	100	
Control (water) ..	41	1	61.0	
Control (water) ..	41	4	80.0	
0.1%	294	1-2	100	4.5 grams of treatment solution per cubic inch of soil (damp sand)
Control (water) ..	79	1-2	36.7	

[a] Lilly's go-West Slug Killer--Metaldehyde 25% EC: Manufactured by Charles H. Lilly Co., Inc., Portland, Oregon.

[b] Miller's Liquid Sevin Insect Spray 10%--carbaryl: Manufactured by Charles H. Lilly Co., Inc., Portland, Oregon.

TABLE VIII. RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Soil pH	Percent Mortality	Dosage
Metaldehyde 25% EC[a]				
0.5% + sodium hydroxide	30 adults (w/shells 50-80 mm long) per treatment	9.0 to 7.5	46.7	Drench: 2 grams of treatment solution per cubic inch of soil (volconite 2.7: peat 1 parts by weight)
1% + sodium hydroxide		9.0 to 7.5	60.0	
0.5% + phosphoric acid		4.6 to 4.9	63.3	
1% + phosphoric acid		4.6 to 4.9	83.3	
Control (water) ..	10 adults (w/shells 50-80 mm long)		0	
0.01%	5 infants (3-wk old)		0	Drench: 2.99 grams of treatment solution per cubic inch of soil (vermiculite)
0.01%	5 young (8-wk old)		0	
0.01%	5 young (12-wk old)		0	
0.01%	5 adults (shells 50-80 mm long)		80.0	
0.1%	5 infants (3-wk old)		20.0	
0.1%	5 young (8-wk old)		0	
0.1%	5 young (12-wk old)		0	
0.1%	5 adults (shells 50-80 mm long)		100	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Percent Mortality	Dosage
(Cont.) Metaldehyde 25% EC[a]			
1%	5 infants (3-wk old)	100	Drench: 2.99 grams of treatment solution per cubic inch of soil (vermiculite)
1%	5 young (8-wk old)	100	
1%	5 young (12-wk old)	100	
1%	5 adults (shells 50-80 mm long)	100	
5%	5 infants (3-wk old)	100	
5%	5 young (8-wk old)	100	
5%	5 young (12-wk old)	100	
5%	5 adults (shells 50-80 mm long)	100	
methylene chloride[b]			
0.6%	5/qt. pot	60.0	Dip: Pots (Fig. 11), containing *A. fulica* (4-5 months old, with $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shells, buried in soil --peat and top-soil 1:1 by volume), immersed in treatment solution for 30 minutes (Fig.10)
0.6%	5/gal. pot	100	
0.3%-Sevin WP 0.3%	5/qt. pot	100	
0.3%-Sevin WP 0.3%	5/gal. pot	100	
0.2%-Sevin WP 0.2% -xylene 0.2%	5/qt. pot	80.0	
0.2%-Sevin WP 0.2% -xylene 0.2%	5/gal. pot	80.0	
0.3%-xylene 0.3%	5/qt. pot	60.0	
0.3%-xylene 0.3%	5/gal. pot	100	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Percent Mortality	Dosage
(Cont.) methylene chloride[b]			
1%	5/qt. pot	60.0	Dip: Pots (Fig. 11), containing *A. fulica* (4-5 mos. old, with $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shells, buried in soil--peat and topsoil 1:1 by volume), immersed in treatment solution for 30 min. (Fig. 10).
1%	5/gal. pot	80.0	
1%	5/qt. pot	100	
1%	5/gal. pot	100	
2%	5/qt. pot	100	
2%	5/gal. pot	100	
carbaryl:			
Carin 24.4% Liquid Sevin[c]			
0.1%	5/qt. pot	20.0	Dip: Pots (Fig. 11), containing *A. fulica* (4-5 mos. old, with $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shells, buried in soil--peat and topsoil 1:1 by volume), immersed in treatment solutions for 30 min. (Fig. 10).
0.1%	5/gal. pot	80.0	
1%	5/qt. pot	80.0	
1%	5/gal. pot	100	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Percent Mortality	Dosage
(Cont.) carbaryl:			
Carin 24.4% Liquid Sevin[c]			
1%	5/qt. pot	80.0	Dip: Pots (Fig. 11), containing *A. fulica* (4-5 mos. old, with 5½-6½-whorl shells, buried in soil--peat and topsoil 1:1 by volume), immersed in treatment solution for 45 min. (Fig. 10).
1%	5/gal. pot	100	
0.5%	30 (4-5 mos. old, with shells consisting of 5½-6½ whorls)	3.3	Drench: 4.5 grams of treatment solution per cubic inch of soil (volconite and peat 1:1 by volume); tubs filled with 7" high of soil and 10 *A. fulica*/tub buried in soil (Fig. 12).

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Soil pH	Percent Mortality	Dosage
(Cont.) carbaryl:				
Miller's Liq. Sevin Insect Spray 10%[d]				
0.05% + sodium hydroxide	30 adults (shells 50-80 mm long) per treatment	8.8 to 7.4	3.3	Drench: 2 grams of treatment solution per cubic inch of soil (peat and topsoil 1:1 by volume)
0.1% + sodium hydroxide		8.8 to 7.4	40.0	
0.05% + phosphoric acid		4.6 to 4.7	3.3	
0.1% + phosphoric acid		4.6 to 4.7	0	
Control (water) ..	10 adults (shells 50-80 mm long)		0	
0.1% on Florida soil composition #1	20 adults (shells 50-80 mm long; 10 active and 10 in a state of aestivation) per treatment		100	Drench: 4.5 grams of treatment solution per cubic inch of soil
0.1% on Florida soil composition #2			100	
0.1% on Florida soil composition #3			100	
0.1% on Florida soil Opalocka composition			100	
0.1% on Florida soil gray marl composition			100	
0.1% on Florida soil potato land and sandy-coral rock composition			100	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Percent Mortality	Dosage
(Cont.) carbaryl:			
Miller'S Liq. Sevin .... 10%[d]			
0.01%	5 infants (3-wk old)	0	Drench: 2.99 grams of treatment solution per cubic inch of soil (vermiculite)
0.01%	5 young (8-wk old)	0	
0.01%	5 young (12-wk old)	0	
0.01%	5 adults (shells 50-80 mm long)	0	
0.1%	5 infants (3-wk old)	100	
0.1%	5 young (8-wk old)	100	
0.1%	5 young (12-wk old)	100	
0.1%	5 adults (shells 50-80 mm long)	100	
1%	5 infants (3-wk old)	100	
1%	5 young (8-wk old)	100	
1%	5 young (12-wk old)	100	
1%	5 adults (shells 50-80 mm long)	100	
5%	5 infants (3-wk old)	100	
5%	5 young (8-wk old)	100	
5%	5 young (12-wk old)	100	
5%	5 adults (shells 50-80 mm long)	100	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Percent Mortality	Dosage
(Cont.) carbaryl:			
Miller's Liq. Sevin .... 10%[d]			
0.05%	30 adults (shells 50-80 mm long) per treatment	16.7	Drench: 2.5 grams of treatment solution/cu. in. of soil (volconite and peat 2.7:1 by weight)
0.1%		20.0	
0.1%		36.7	
0.5%		100	
1%		100	
0.1%	30 adults (shells 50-80 mm long) per treatment	83.3	Drench: 3.5 grams of treatment solution/cu. in. of soil (volconite and peat 2.7:1 by weight)
0.1%	30 adults (shells 50-80 mm long) per treatment	100	Drench: 4.5 grams of treatment solution/cu. in. of soil (volconite and peat 2.7:1 by weight)
0.1%	5/qt. pot	100	Dip: Pots (Fig. 11), containing *A. fulica* (5 mos. old, w/6½-whorl shell) buried in soil (peat and volconite 1:1 by volume), immersed in treatment solution for 30 min. (Fig. 10).
0.1%	5/gal. pot	100	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Percent Mortality	Dosage
(Cont.) carbaryl:			
Ortho Sevin Garden Spray 50% WP[e]			
0.5%	30 adults (shells 50-80 mm long)	0	Drench: 4 grams of treatment solution/cu. in. of soil (volconite and peat 1:1 by volume)
0.1%	5/qt. pot	0	Dip: Pots (Fig. 11), containing *A. fulica* (4-5 mos. old, with $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shell, buried in soil--peat and topsoil 1:1 by volume), immersed in treatment solutions for 30 min. (Fig. 10).
0.1%	5/gal. pot	20.0	
1%	5/qt. pot	80.0	
1%	5/gal. pot	80.0	
0.3%-methylene chloride 0.3% ..	5/qt. pot	100	
0.3%-methylene chloride 0.3% ..	5/gal. pot q	100	
0.3%-xylene 0.3%	5/qt. pot	60.0	
0.3%-xylene 0.3%	5/gal. pot	100	
0.2%-methylene chloride 0.2%-xylene 0.2%	5/qt. pot	80.00	
0.2%-methylene chloride 0.2%-xylene 0.2%	5/gal. pot	80.0	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST *ACHATINA FULICA* BOWDICH.

Chemical/Formulation	Number of *A. fulica*	Percent Mortality	Dosage
(Cont.) carbaryl:			
Sevimol® 4 40.38% (in molasses)[f]			
0.5%	5/qt. pot	20.0	Dip: Pots (Fig. 11), containing *A. fulica* (4-5 mos. old, with $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shell, buried in soil--peat and topsoil 1:1 by volume), immersed in treatment solution for 45 min. (Fig. 10).
0.5%	5/gal. pot	80.0	
1%	5/qt. pot	100	
1%	5/gal. pot	100	
Soilserv's Sevin® 25% EC[g]			
0.5%	5/qt. pot	20.0	Dip: Pots (Fig. 11), containing *A. fulica* (4-5 mos. old, with $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shell, buried in soil--peat and topsoil 1:1 by volume), immersed in treatment solution for 30 min. (Fig. 10).
0.5%	5/gal. pot	80.0	
1%	5/qt. pot	100	
1%	5/gal. pot	100	

TABLE VIII. (CONTINUED) RESULTS OF MOLLUSCICIDAL TESTS (CONSISTING OF DRENCH AND DIP TREATMENTS) AGAINST ACHATINA FULICA BOWDICH.

Chemical/Formulation	Number of A. fulica	Percent Mortality	Dosage
xylene[h]			
0.5%	5/qt. pot	0	Dip: Pots (Fig. 11), containing A. fulica (5 mos. old, with $6\frac{1}{2}$-whorl shell buried in soil --volconite and peat 1:1 by volume), immersed in treatment solutions for 30 min. (Fig. 10).
0.5%	5/gal. pot	100	
1%	5/qt. pot	100	
1%	5/gal. pot	100	
2%	5/qt. pot	100	
2%	5/gal. pot	80.0	
0.6%	5/qt. pot	20.0	Dip: Pots (Fig. 11), containing A. fulica (4-5 mos. old, with $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shell, buried in soil--peat and topsoil 1:1 by volume), immersed in treatment solutions for 30 min. (Fig. 10).
0.6%	5/gal. pot	80.0	
0.3%-Sevin WP 0.3%	5/qt. pot	60.0	
0.3%-Sevin WP 0.3%	5/gal. pot	100	
0.3%-methylene chloride 0.3%	5/qt. pot	60.0	
0.3%-methylene chloride 0.3%	5/gal. pot	100	
0.2%-methylene chloride 0.2%-Sevin WP 0.2%	5/qt. pot	80.0	
0.2%-methylene chloride 0.2%-Sevin WP 0.2%	5/gal. pot	80.0	

[a] Lilly's go-West Slug Killer--Metaldehyde 25% EC: Manufactured by Charles H. Lilly Co., Inc., Portland, Oregon.

[b] Methylene chloride 100%--reagent: Manufactured by Merck & Co., Inc., Rahway, New Jersey.

[c] Carbaryl--Carin 24.4% Liquid Sevin: Manufactured by Woodbury Chemical Co., St. Joseph, Missouri.

[d] Carbaryl--Miller's Liquid Sevin Insect Spray 10%: Manufactured by Charles H. Lilly Co., Inc., Portland, Oregon.

[e] Carbaryl--Ortho Sevin Garden Spray 50% WP: Manufactured by Chevron Chemical Co., Richmond, California.

[f] Carbaryl--Sevimol® 4 (carbaryl insecticide 40.38% in molasses): Manufactured by Union Carbide Corporation, New York, N. Y.

[g] Carbaryl--Soilserv's Sevin® 25% EC: Manufactured by Soilserv, Inc., Salinas, California.

[h] Xylene 100%--reagent consisting mostly of m-Xylene (ENT-8197) but also containing o-Xylene (ENT-8916) and p-Xylene (ENT-52255): Manufactured by J. T. Baker Chemical Co., Phillipsburg, New Jersey, and Merck and Co., Inc., Rahway, N. J.

TABLE IX. RESULTS OF MOLLUSCICIDAL-PHYTOTOXICITY DIP TREATMENT TESTS AGAINST <u>ACHATINA FULICA</u> BOWDICH AND NURSERY PLANT HOSTS OF <u>ACHATINA FULICA</u> BOWDICH.

Chemical/ Formulation	N (plants)	Phyto-toxicity Rating 0-3[a]	Percent Mortality of *A. fulica*	Dosage
carbaryl:				
Miller's Liq. Sevin Insect Spray 10%[b]				
0.05%	2 *Citrus* spp.	0	100	Pots, each containing a plant, soil, and one *A. fulica* (4-5 mos. old, w/ $5\frac{1}{2}$-$6\frac{1}{2}$-whorl shell) buried in the soil around the plant's roots, immersed in treatment solutions for 30 minutes.
0.05%	2 *Codiaeum variegatum*	0	100	
0.05%	2 *Hibiscus* sp.	3	100	
0.05%	2 *Philodendron* sp.	1	50	
0.1%	2 *Citrus* sp.	0	100	
0.1%	2 *C. variegatum*	0	100	
0.1%	2 *Hibiscus* sp.	3	100	
0.1%	2 *Philodendron* sp.	1 & 3	50	
0.5%	1 *Areca* sp.	1	100	
0.5%	1 *Begonia* sp.	1	100	
0.5%	1 *Citrus* sp.	3	100	
0.5%	1 *C. variegatum*	3	100	
0.5%	1 *Ficus elastica*	2	100	
0.5%	1 *Gardenia jasminoides*	2	100	
0.5%	1 *Hibiscus* sp.	3	100	
0.5%	1 *Nephrolopsis* sp.	2	100	
0.5%	1 *Philodendron selloum*	3	100	
0.5%	1 *Ixora casei*	3	100	
1%	1 *Areca* sp.	1	100	
1%	1 *Begonia* sp.	1	100	
1%	1 *Citrus* sp.	3	100	
1%	1 *C. variegatum*	3	100	
1%	1 *F. elastica*	2	100	
1%	1 *G. jasminoides*	3	100	
1%	1 *Hibiscus* sp.	3	100	
1%	1 *Nephrolopsis* sp.	2	100	
1%	1 *Philodendron* sp.	3	100	
1%	1 *Ixora casei*	3	100	

TABLE IX. (CONTINUED) RESULTS OF MOLLUSCICIDAL-PHYTOTOXICITY DIP TREATMENT TESTS AGAINST *ACHATINA FULICA* BOWDICH AND NURSERY PLANT HOSTS OF *ACHATINA FULICA* BOWDICH.

Chemical/ Formulation	N (plants)	Phyto- toxicity Rating 0-3[a]	Percent Mortality of *A. fulica*	Dosage
carbaryl:				
Ortho Sevin Garden Spray[c] 50% WP				
0.5%	1 *Areca* sp.	1	0	Pots, each containing a plant, soil, and one *A. fulica* (4-5 mos. old, w/ 5½-6½-whorl shell) buried in the soil around the plant's roots, immersed in treatment solutions for 30 minutes.
0.5%	1 *Begonia* sp.	1	0	
0.5%	1 *Citrus* sp.	0	0	
0.5%	1 *Codiaeum variegatum*	0	0	
0.5%	1 *Ficus elastica*	0	0	
0.5%	1 *Gardenia jasminoides*	0	0	
0.5%	1 *Hibiscus* sp.	0	0	
0.5%	1 *Nephrolopsis* sp.	1	0	
0.5%	1 *Philodendron selloum*	0	100	
0.5%	1 *Ixora casei*	1	100	
1%	1 *Areca* sp.	1	0	
1%	1 *Begonia* sp.	1	100	
1%	1 *Citrus* sp.	0	100	
1%	1 *C. variegatum*	0	0	
1%	1 *F. elastica*	0	0	
1%	1 *G. jasminoides*	0	100	
1%	1 *Hibiscus* sp.	0	100	
1%	1 *Nephrolopsis* sp.	0	0	
1%	1 *P. selloum*	0	100	
1%	1 *Ixora casei*	0	0	
methylene chloride[d]				
1%	1 *Citrus* sp.	0		Potted plants immersed in treatment solutions for 30 minutes.
1%	1 *C. variegatum*	0		
5%	1 *Citrus* sp.	0		
5%	1 *C. variegatum*	0		

TABLE IX. (CONTINUED) RESULTS OF MOLLUSCICIDAL-PHYTOTOXICITY DIP TREATMENT TESTS AGAINST *ACHATINA FULICA* BOWDICH AND NURSERY PLANT HOSTS OF *ACHATINA FULICA* BOWDICH.

Chemical/ Formulation	N (plants)	Phyto- toxicity Rating 0-3[a]	Dosage
xylene[e]			
1%	1 *Citrus* sp.	1	Potted plants immersed in treatment solutions until soil was saturated.
1%	1 *Codiaeum variegatum*	1	
2%	1 *C. variegatum*	1	
2%	1 *Hibiscus* sp.	1	

[a] Phytotoxicity Rating: 0 = None; 1 = Slight; 2 = Moderate; and 3 = Severe.

[b] Carbaryl--Miller's Liquid Sevin Insect Spray 10%: Manufactured by Charles H. Lilly Co., Inc., Portland, Oregon.

[c] Carbaryl--Ortho Sevin Garden Spray 50% WP: Manufactured by Chevron Chemical Co., Richmond, California.

[d] Methylene chloride 100%--reagent: Manufactured by Merck & Co., Inc., Rahway, New Jersey.

[e] Xylene 100%--reagent, consisting mostly of m-Xylene (ENT-8197) but also containing *o*-Xylene (ENT-8916) and *p*-Xylene (ENT-52255): Manufactured by J. T. Baker Chemical Co., Phillipsburg, New Jersey.

TABLE X. RESULTS OF TREATED-FOLIAGE FEEDING TESTS AGAINST *ACHATINA FULICA* BOWDICH.

Treatment/ Formulation	Number of *A. fulica*	Number of Days *A. fulica* Feeding on Manoa Lettuce Dipped in Treatment Solution / Percent Mortality
PolyTrap® [a]		
1%	6 adults (shells 50-80 mm long) per treatment	12 Days / 0% Kill
4%		
5%		
10%		
1%	10 young (6-wk old) per treatment	13 Days / 100% Kill*
Control (water)		
2%	10 young (6-wk old) per treatment	13 Days / 90% Kill*
Control (water)		13 Days / 30% Kill*
100%	10 adults (shells 50-80 mm long) per treatment	14 Days / 0% Kill
100% (Special #1)		
100% (Special #2)		
1%	33 infants (3-5-wk old) per treatment	14 Days / 3.0% Kill
2%		
3%		
Control (water)		14 Days / 0% Kill
5%	33 young (6-8-wk old) per treatment	14 Days / 0% Kill
5% (Special #1)		14 Days / 3.0% Kill
5% (Special #2)		14 Days / 3.0% Kill
Control (water)		14 Days / 0% Kill
5%	60 infants (4-8-wk old)	30 Days / 0% Kill

TABLE X. (CONTINUED) RESULTS OF TREATED-FOLIAGE FEEDING TESTS AGAINST *ACHATINA FULICA* BOWDICH.

Treatment/ Formulation	Number of *A. fulica*	Number of Days *A. fulica* Feeding on Manoa Lettuce Dipped in Treatment Solution / Percent Mortality
Miller's Liq. Sevin Insect Spray 10%[b]		
0.1%	41 infants (1 wk. old)	1 2 3 4 Days 24.4 65.9 90.2 100 % Kill
0.1%	30 infants (1½ mos. old)	21 Days 0% Kill
0.1%	20 young (2½ mos. old)	21 Days 0% Kill
0.1%	10 young (3½ mos. old)	21 Days 0% Kill
0.2%	30 infants (1½ mos. old)	8 29 34 38 Days 50 60 70 70 % Kill
0.2%	20 young (2½ mos. old)	8 29 34 38 Days 0 5 5 10 % Kill
0.2%	10 young (3½ mos. old)	8 29 34 38 Days 10 10 10 10 % Kill
0.4%	30 infants (1½ mos. old)	4 8 12 17 25 32 38 Days 36.7 73.3 83.3 100 -- -- -- % Kill
0.4%	20 young (2½ mos. old)	4 8 12 17 25 32 38 Days 15 15 30 55 70 90 90 % Kill
0.4%	10 young (3½ mos. old)	4 8 12 17 25 32 38 Days 20 30 40 50 90 100 -- % Kill

* Mortality attributed to unknown factors and not to PolyTrap.

[a] PolyTrap® --plant spray protectant, anti-transpirant: Manufactured by Green-O-Matic Systems, San Diego, California.

[b] Miller's Liquid Sevin Insect Spray 10%: Manufactured by Charles H. Lilly Co., Inc., Portland, Oregon.

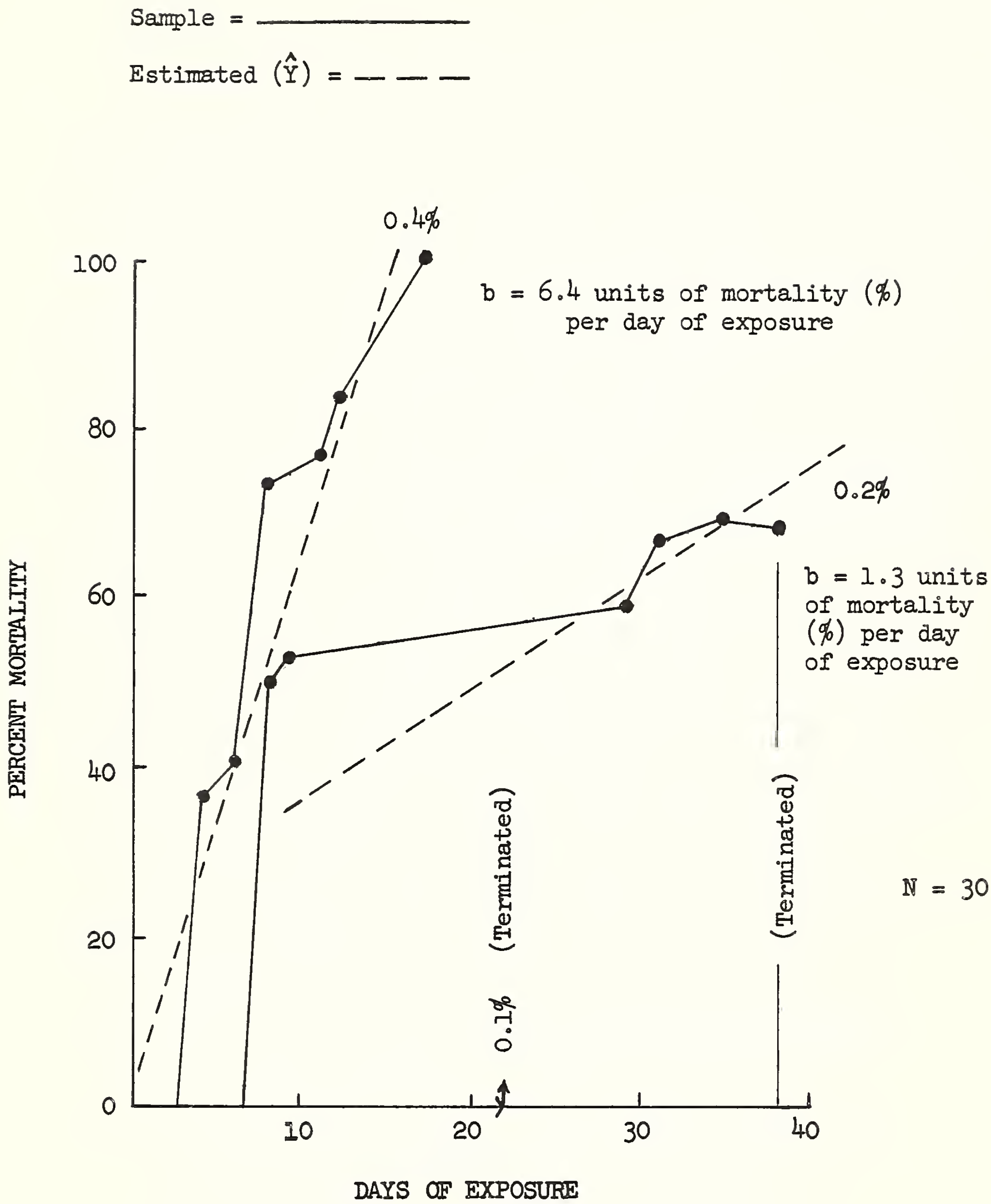

Figure 16. Regression of mortality of $1\frac{1}{2}$ months old Achatina fulica Bowdich to days of exposure to lettuce dipped in 0.1%, 0.2%, and 0.4% a.i. solutions made from Miller's Liquid Sevin Insect Spray 10%.

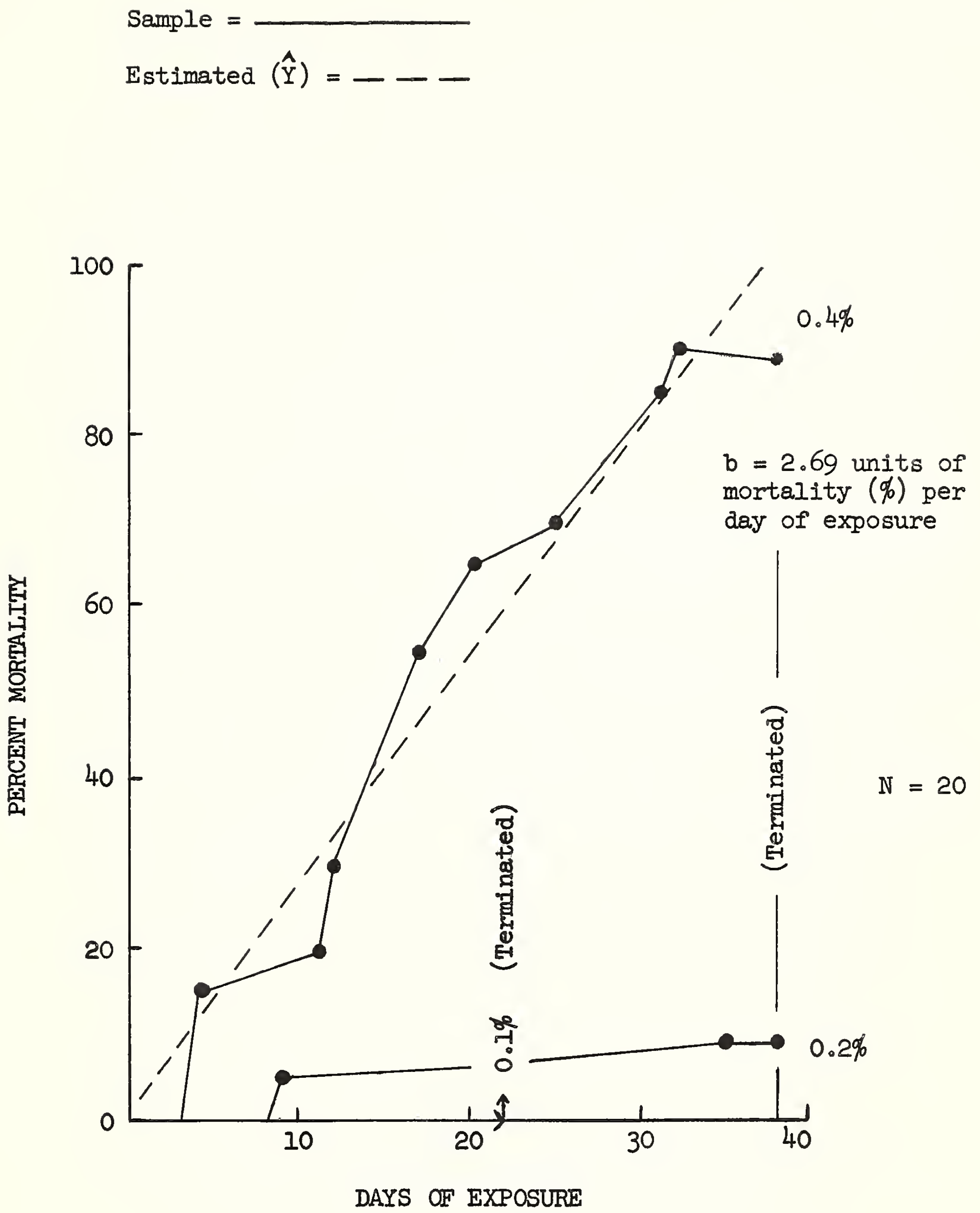

Figure 17. Regression of mortality of $2\frac{1}{2}$ months old *Achatina fulica* Bowdich to days of exposure to lettuce dipped in 0.1%, 0.2%, and 0.4% a.i. solutions made from Miller's Liquid Sevin Insect Spray 10%.

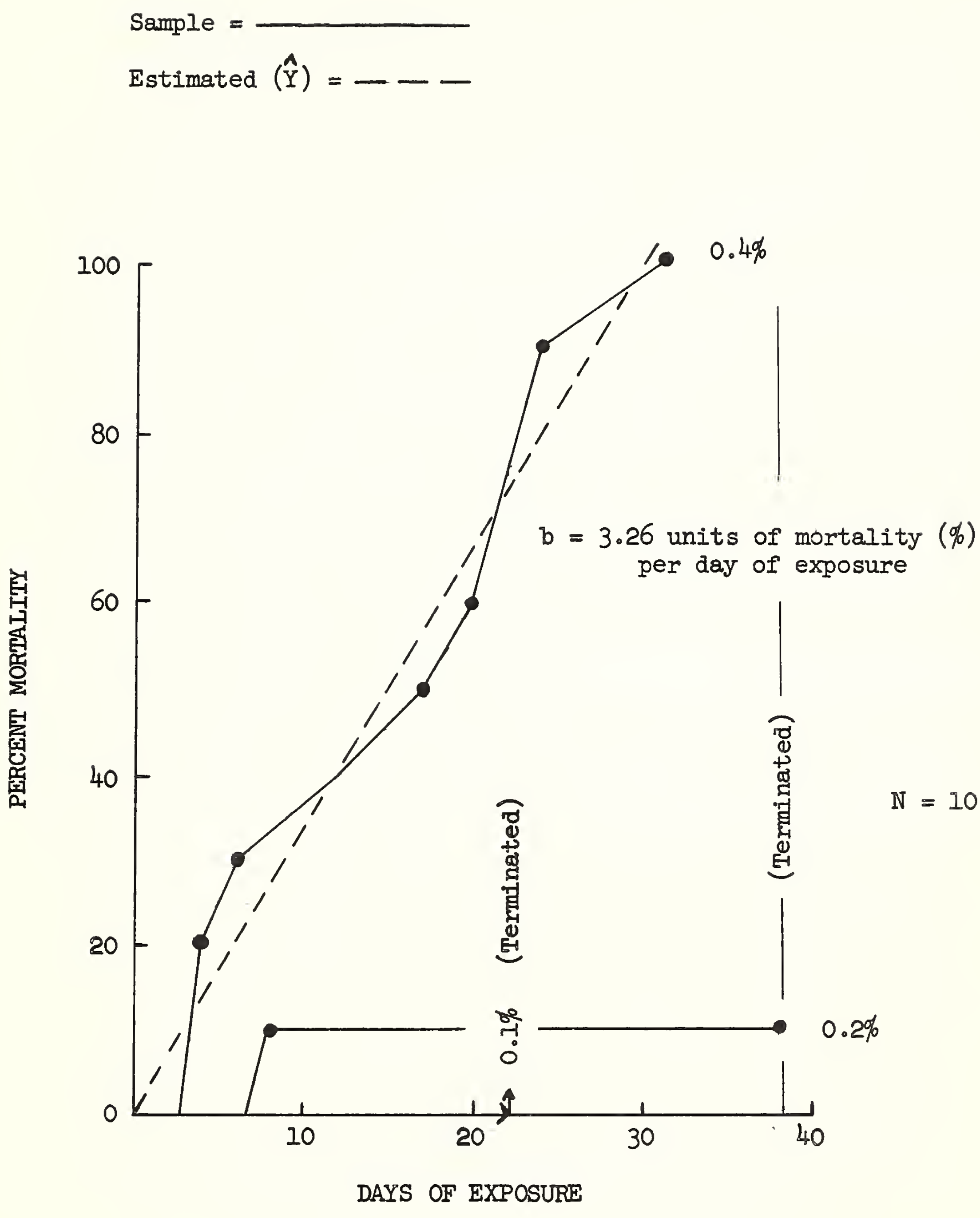

Figure 18. Regression ~~of mortality~~ of $3\frac{1}{2}$ months old Achatina fulica Bowdich to days of exposure to lettuce dipped in 0.1%, 0.2%, and 0.4% a.i. solutions made from Miller's Liquid Sevin Insect Spray 10%.

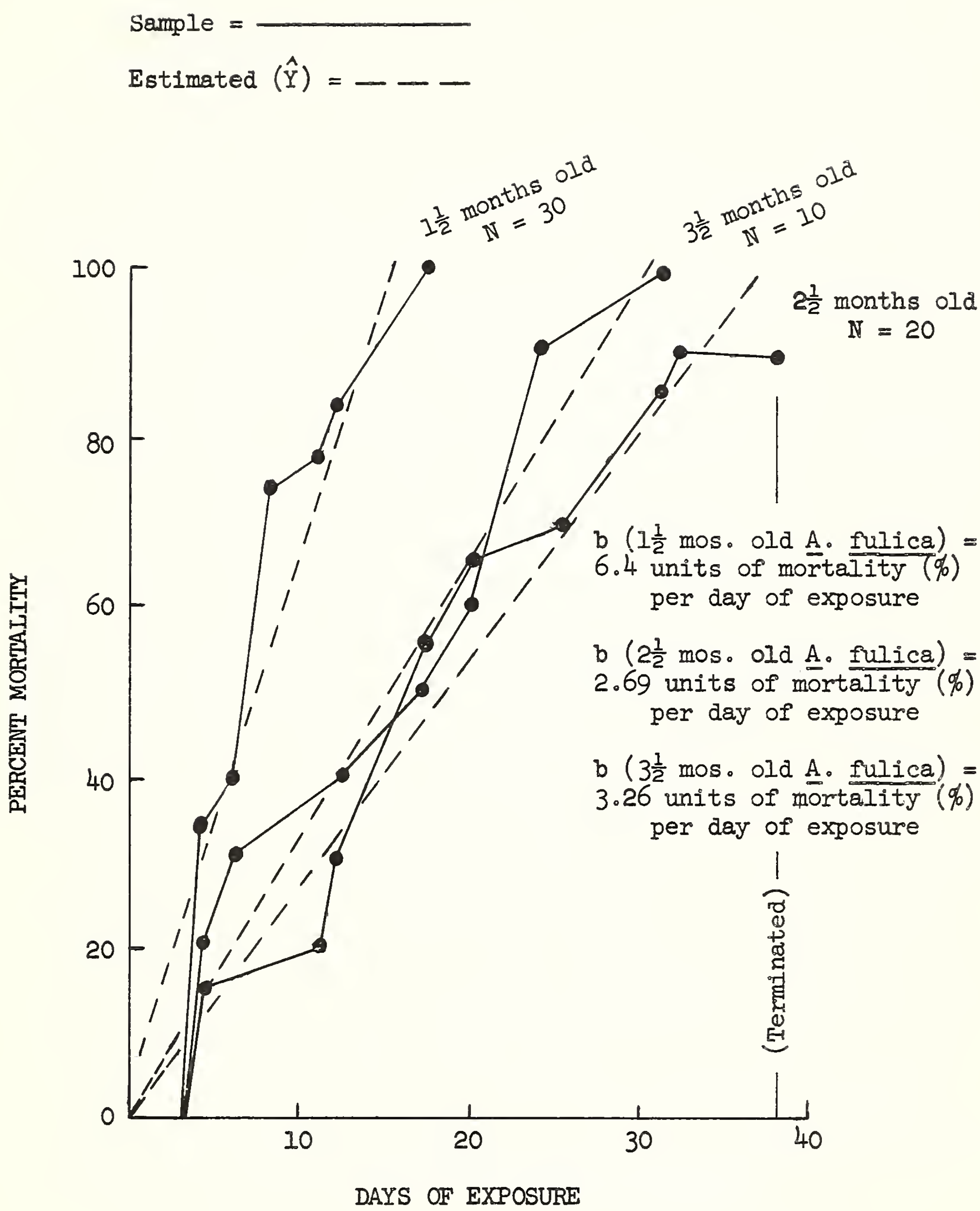

Figure 19. Regression of mortality of $1\frac{1}{2}$, $2\frac{1}{2}$, and $3\frac{1}{2}$ months old *Achatina fulica* Bowdich to days of exposure to lettuce dipped in 0.4% a.i. solutions made from Miller's Liquid Sevin Insect Spray 10%.

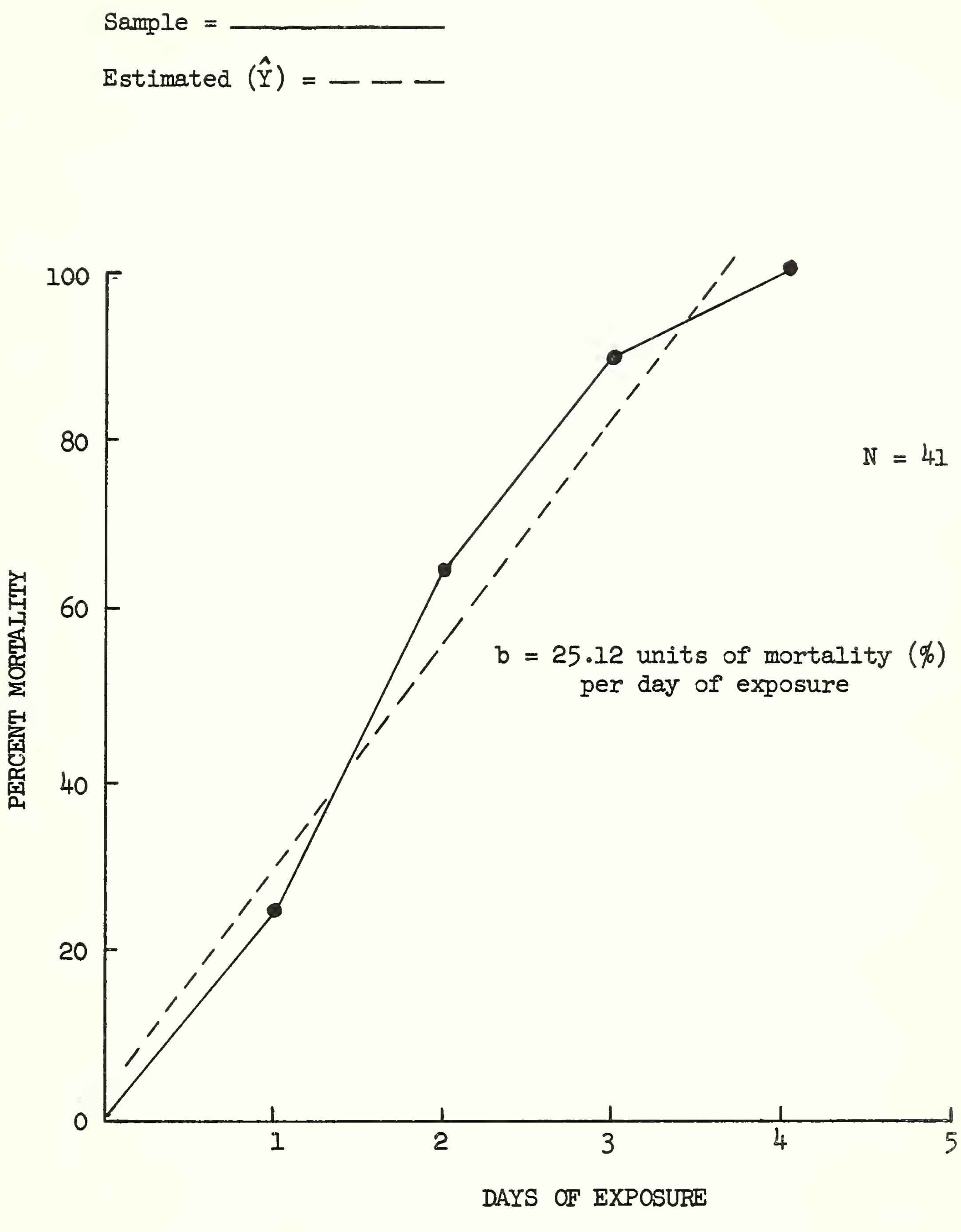

Figure 20. Regression of percent mortality of one week old infant *Achatina fulica* Bowdich to days of exposure to lettuce dipped in 0.1% a.i. solution made from Miller's Liquid Sevin Insect Spray 10%.

DISCUSSION AND CONCLUSIONS

It is important to mention data developed on the biology and behavior of A. fulica incidental to the screening of candidate molluscicides. Some of this information is new and some will help resolve conflicts in literature.

On self-fertilization, seven virgin A. fulica reared from eggs that hatched May 26, 1971, and kept isolated for one year laid a total of 84 eggs. The range was 4-32 eggs. The mean was 11.7 eggs per A. fulica. Three of the 84 eggs were viable. (Self-fertilization had taken place.) In one of the viable eggs, the infant A. fulica developed but died in the egg before eclosion. The other two viable eggs hatched, but the two infant A. fulica died soon after hatching. One of the virgin A. fulica began laying eggs January 5, 1972 (7 mos. old).

In A. fulica, there is a decrease in fecundity and an increase in sterility with elapsed time from sexual maturity. The work of J. C. van der Meer Mohr (1956) supports this thesis. A. fulica lays most of its eggs during its first year of active life, i.e., not including time spent in aestivation. Four of my paired A. fulica laid a total of 2,848 eggs starting January 5, and ending July 16, 1972. One of the paired A. fulica was sterile, and its mate had to be mated with a fertile A. fulica. This delay in mating with a fertile partner caused this particular A. fulica a delay in laying its compliment of eggs during the egg-laying period concurrent with sexual maturity. It laid an additional clutch of 283 eggs at 19 months of age (seven months after termination of the first egg-laying period. Many of these eggs were sterile. Six of seven virgin A. fulica paired at one year of age

failed to produce any eggs (paired for 11 months through April 1973). One of the seven, paired for 10 months, laid a clutch of 140 eggs March 23, 1973.

Mead (1961) places the normal life span of <u>A. fulica</u> at five years. Results of my tests in Hawaii indicate the life span is less than two years and probably closer to one year. The longest shell found in nature consisted of 7½ whorls and measured 106.1 x 55 mm. Shells of 11 cultured <u>A. fulica</u> measured 93 x 46 mm to 106 x 50.2 mm at 7½ months, all with 7½ whorls. At one year of age, their shell size ranged from 105 x 52.5 mm to 144 x 63 mm. Seven of the 11 <u>A. fulica</u> had shells of 8½ whorls. This suggests that the <u>A. fulica</u> occurring in nature live less than one year of active life.

Schreurs (1963) used time (6½ months) and Kondo (1952) used length of shell (35 mm) to indicate sexual maturity. Based on observations in nature and data obtained from cultured <u>A. fulica</u>, sexual maturity occurs first when the shell has 6½ whorls. The shell of the fast developing <u>A. fulica</u> usually has 7½ whorls by the time the first clutch of eggs is laid. The 6½-whorl minimum is in line with Kondo's criteria. The size of 170 6½-whorl shells measured ranged from 40.5 x 36 mm to 80 x 46 mm. The size range of 100 5½-whorl shells measured was 23.5 x 16 mm to 44.4 x 25.7 mm. One of my <u>A. fulica</u> went from egg to egg in 5 months and 12 days. It had a shell of 7½ whorls.

Most of the empty shells of <u>A. fulica</u> found in Hawaii have 6½ whorls. One can speculate that these <u>A. fulica</u> reached sexual maturity, laid their compliment of 4-6 clutches of eggs over a 4-6-month period, and then having fulfilled their purpose in life, died a natural death.

Approximately 7,000 A. fulica were used in the screening tests. The process for screening candidate molluscicides was designed to indicate those chemicals that had contact poisoning action, and contact and stomach poisoning action. However, stomach poisoning action could not be demonstrated with those chemicals in baits that A. fulica rejected (refused to eat). The screening process missed those chemicals which have only stomach poisoning action.

Determining both contact and stomach poisoning action for each chemical would have entailed screening each in a contact and a bait treatment. Stomach poisoning action could also have been determined by injecting a given amount of each chemical into the alimentary canal of A. fulica as Hunter and Johnston (1965) did with the slug, Agriolimax reticulatus (Müller). The problem of A. fulica withdrawing into its shell would have to be overcome.

Those chemicals in Phase I (Table IV) which gave 83.3-100% mortality and could be obtained in baits or a sufficient amount could be obtained from which baits could be made were screened as baits in Phase II and/or III (Tables V and VI).

In some cases, chemicals which did not qualify for further testing were screened as baits in Phases II and III (Tables IV, V, and VI). This was done as a check of my screening system, e.g., triphenyl tin hydroxide gave 50% mortality in Phase I (Table V) at 90 lbs. a.i./acre; 33.3%, 83.3%, and 33.3% mortalities in Phase II (Table V) as 2%, 4%, and 8% a.i. baits at 3, 6, and 12 lbs. a.i./acre respectively; and 63.6%, 87.9%, and 97.0% mortalities of A. fulica as 2%, 4%, and 8% a.i. baits at 3, 6, and 12 lbs. a.i./acre respectively in Phase III (Table VI).

Triphenyl tin hydroxide demonstrated a high degree of stomach poisoning action. Had it not been tested as a bait, despite moderate mortality in the Phase I test, this information would have been missed.

Carbanolate, fenazalor, chlorpyrifos, and Stauffer R-14805 were also tested as baits in Phase II as a check against the Phase I screening tests. Carbanolate and fenazaflor 2%, 4%, and 8% a.i. baits at 3, 6, and 12 lbs. a.i./acre gave 0%, 16.6%, 0%, and 0%, 50%, 0% mortalities respectively. Chlorpyrifos 2% a.i. bait at 3 lbs. a.i./acre gave 83.3% and 50% mortalities in Phase II. Stauffer R-14805 4% a.i. bait at 6 lbs. a.i./acre gave 0% mortality of A. fulica. Fenazaflor and chlorpyrifos were field tested as 2% and 4% a.i. baits at 3 and 6 lbs. a.i./acre respectively in Phase III, giving 18.2% and 12.1% mortalities respectively.

One hundred and seven candidate molluscicides (46 carbamate, 23 organic phosphate, 19 salicylanilide, 6 tin, and 13 miscellaneous compounds) were screened. Thirty-two (74.4%) of the carbamate, 12 (57.1%) of the organic phosphate, 4 (21.1%) of the salicylanilide, 3 (60%) of the tin, and 1 (14.3%) of the miscellaneous compounds tested in Phase I gave 83-100% mortality of A. fulica or had a 5-6 rating and qualified for further testing (Table IV).

Forty-eight candidate molluscicides (27 carbamate, 12 organic phosphate, 2 salicylanilide, 3 tin, and 4 miscellaneous compounds) were screened as baits in the Phase II bait tests. Fourteen (51.9%) of the carbamate, 4 (33.3%) of the organic phosphate, 1 (50%) of the salicylanilide, 2 (66.6%) of the tin, and 2 (50%) of the miscellaneous compounds tested in Phase II gave 66-100% mortality of A. fulica and

qualified for Phase III, field testing.

A. fulica did not feed on baits containing Zectran®, 2',4',6'-tribromo-3-nitrosalicylanilide, and tributyl tin oxide. These candidate molluscicides had stomach poisoning action against A. fulica and were tested as 4% a.i. baits in the Phase III field tests. Most of the data from the field test of tributyl tin oxide was lost because two of three cages had been dislodged and the A. fulica escaped. There was 9.1% mortality in the third cage. Mortality from Zectran® and 2',4',6'-tribromo-3-nitrosalicylanilide was also low.

Carbaryl, fenazaflor, and Azodrin® were field tested as baits even though they didn't qualify. They were field tested as a check against the Phase II bait screening process.

Forty candidate molluscicides (21 carbamate, 9 organic phosphate, 2 salicylanilide, 5 tin, and 3 miscellaneous compounds) were tested in Phase III, field tests. These compounds were field tested mostly as baits.

The carbamate compounds demonstrated the highest degree of contact molluscicidal action against A. fulica. Of the 45 carbamate compounds screened in Phase I, 82.2% killed 50-100% of the A. fulica. The tin compounds were the next most active group, 80% killed 50-100% of the A. fulica in the Phase I screening tests. With the remaining groups, 66.6% of the organic phosphate, 21.1% of the salicylanilide, and 14.3% of the miscellaneous compounds killed 50-100% of the A. fulica in the Phase I screening tests.

Candidate molluscicides screened in Phase I when compared with the same compounds screened as baits in Phases II and III reflect which

compounds have both contact and stomach poisoning action against A. fulica (Tables IV, V, and VI). Using 50-100% mortality as the standard, i.e., 50-100% mortality in Phase I plus 50-100% mortality in Phase II or Phase III tests, the compounds with both contact and stomach poisoning action can be identified.

Carbamate compounds, Isolan®, Hercules 5727, Mesurol®, carbofuran, dioxacarb, Union Carbide's UC-30044 and UC-30045; Ciba's C-10015 and C-9643, fenazaflor, formetanate HCl, Bay 78389; Shell's SD-8530, SD-17250, and SD-17578; organic phosphate compounds, disulfoton, phorate, Azodrin®, and Chevron Ortho® 9006; the salicylanilide, 3,4',5-tribromosalicylanilide; tin compounds, triphenyl tin hydroxide, triphenyl tin acetate, and Pennwalt TD-5032; and miscellaneous compounds, dinitrobutylphenol and metaldehyde demonstrated contact-stomach poisoning action against A. fulica. Shell SD-17250, Union Carbide UC-30045, Pennwalt TD-5032, and triphenyl tin acetate were the most impressive candidate molluscicides screened. SD-17250 and UC-30045 (carbamate compounds) gave 100% mortality in the Phase I test and 97% and 84.8% mortalities of A. fulica respectively in the Phase III test (baits 2% a.i. at 3 lbs. a.i./acre).

Triphenyl tin acetate and Pennwalt TD-5032 (tin compounds) gave 83.3% and 100% mortalities of A. fulica respectively in the Phase I tests. Triphenyl tin acetate as a 4% a.i. bait at 6 lbs. a.i./acre gave 75.7% mortality and Pennwalt TD-5032 as a 2% a.i. bait at 3 lbs. a.i./acre gave up to 84.8% mortality of A. fulica in the Phase III tests.

Candidate molluscicides Isolan®, Hercules 5727, Mesurol®, Bay 78389, Shell SD-17578, disulfoton, phorate, Azodrin®, 3,4',5-

tribromosalicylanilide, and dinitrobutylphenol gave good mortalities of *A. fulica* in Phases I and II but not in Phase III tests. This is an indication that the above baits in the Phase III tests were ineffective because the *A. fulica* did not eat the baits and not that the baits were nonmolluscicidal. The *A. fulica* evidently found the baits less desirable as a food than other natural foods available in the field test cages.

Those compounds such as Shell SD-17250, Union Carbide UC-30045, triphenyl tin acetate, Pennwalt TD-5032, triphenyl tin hydroxide, and Bug-geta®, which gave consistent mortalities of *A. fulica*, were as or more desirable as a food to *A. fulica* than the other natural foods available in the field test cages.

The Stauffer series of organic phosphate compounds, R-15022, R-15996, R-15206, and R-15644, gave 100% mortality of *A. fulica* in the Phase I tests. Stauffer baits made available to me contained 2% a.i. Stauffer compound and 2.6% a.i. metaldehyde. The mortalities obtained in the Phase III tests were 63.6%, 36.4%, 63.6%, and 39.4% respectively. A bait containing 2.6% a.i. metaldehyde alone is capable of giving a comparable range of mortality of *A. fulica*. The conclusion that may be made from this is that most of the mortality was due to the 2.6% a.i. metaldehyde, and the contribution to mortality by the Stauffer compounds was minor.

The above described performance was noted with carbaryl baits containing metaldehyde. Carbaryl 4% a.i. plus metaldehyde 0.5%, 1%, and 3% a.i. baits, in Phase III, gave mortalities of 12.1% and 21.2%; 27.3%, 42.4%, and 48.5%; and 87.9% respectively. Field tests of carbaryl 2%,

4%, and 8% a.i. baits, without metaldehyde, gave 3%, 9.1%, and 9.1% mortalities of A. fulica respectively. This demonstrates that carbaryl has little stomach poisoning action against A. fulica.

Candidate molluscicides which demonstrated a high degree of contact poisoning action (83-100% mortality) but not stomach poisoning action against A. fulica were Pyrolan®; carbaryl; Zectran®; aminocarb; Shell SD-9098; Ciba C-11753, Intl. Minerals & Chemicals, Inc. IMC-48003; Chevron RE-11775; pirimicarb; Stauffer's R-15201, R-15996, R-15206, and R-16745; 2',4',6'-tribromo-3-nitrosalicylanilide; tributyl tin oxide; and methylene chloride.

Chevron Ortho® 5655, promecarb, Bay 42688, Shell SD-16898, 3M Co's MBR-5667 and MBR-6168, Fisons NC-6897, Chevron RE-11776, Stauffer's R-14493 and R-15022, Dowco® 214, 4'-chloro-3-nitro-o-salicylotoluidide, and 2'4'-dichloro-3-nitrosalicylanilide gave 83.3% to 100% mortality of A. fulica in the Phase I tests but could not be obtained as baits or in sufficient amounts to test further.

Bux®, Hercules 9007, Hercules 9418, phosalone, and Stauffer R-15789 demonstrated some contact poisoning action (50-67% mortality) against A. fulica but did not qualify for further testing.

Carbanolate, fenazaflor, chlorpyrifos, and triphenyl tin hydroxide gave 66.7%, 66.7%, 16.7%, and 50% mortalities of A. fulica respectively in the Phase I tests. These compounds were used as a check against the screening process and tested as 2%, 4%, and 8% a.i. baits in the Phase II tests. Carbanolate, fenazaflor, and triphenyl tin hydroxide 4% a.i. baits at 6 lbs. a.i./acre gave 16.7%, 50%, and 83.3% mortalities respectively. Surprisingly, chlorpyrifos 2% a.i. baits at 3 lbs. a.i./

acre gave 83.3% and 50% mortalities respectively. This illustrates that candidate molluscicides with a low-moderate degree of contact poisoning action against *A. fulica* may still have a high degree of stomach poisoning action.

Methomyl, Gardona®, Abate®, Shell SD-14114, and sodium fluosilicate were screened only as baits. Methomyl 2% a.i. bait at 3 lbs. a.i./acre demonstrated a very high degree of stomach poisoning action (83-100% mortality) in the Phase II test but gave a wide varying range of mortality (3-75%) in the Phase III test.

Carbaryl and metaldehyde were selected for intensive testing against *A. fulica* in the Phase IV regulatory treatment development tests (Tables VII-X). Carbaryl demonstrated a high degree of contact poisoning action in Phase I. Metaldehyde has been and remains the standard molluscicide used against *A. fulica*. Both compounds are widely used for pests of fruits and vegetables and are considered relatively safe pesticides. Testing of metaldehyde was discontinued because it lacked the ovicidal action necessary for a regulatory treatment against *A. fulica*. On the other hand, the Miller's formulation of carbaryl was highly ovicidal to the eggs of *A. fulica* (Table VII).

Carbaryl (Miller's formulation) 0.01%, 0.05%, 0.1%, 1%, and 5% a.i. drench treatments against eggs of *A. fulica* gave 75%, 100%, 100%, 100%, and 100% mortalities and/or nonhatch respectively. The same concentrations of metaldehyde gave 25%, 16.2%, 41.7%, 50%, and 87.5% mortalities and/or nonhatch of *A. fulica* eggs.

The Miller's formulation of carbaryl at 0.1%, 1%, and 5% a.i. in drench treatments applied at 2.99 grams of solution per cubic inch of

soil (vermiculite) gave 100% mortality of A. fulica adults, young, and infants. The same treatments with metaldehyde failed to give 100% mortality of all the age groups at the 0.1% a.i. dosage (Table VIII).

Five formulations of carbaryl were tested in the Phase IV regulatory treatment development tests. This was done because the Miller's formulation, when used as a regulatory drench or dip treatment (0.5% and 1% a.i. solutions), was phytotoxic to 10 different species of plants. Phytotoxicity also showed up in treatments of 0.05% and 0.1% a.i. solutions (Table IX).

The emulsifiable concentrate (EC) formulations of carbaryl (Miller's Liquid Sevin Insect Spray 10% and Soilserv's Sevin®) were more molluscicidal against A. fulica than the non-emulsifiable concentrate formulations (Table VIII). This suggested that the inert ingredients in the EC formulations were contributing to the molluscicidal action.

The label on Miller's Liquid Sevin Insect Spray 10% doesn't specifically indicate that it is an emulsifiable concentrate, but the material contained in the bottle has all the appearance of an emulsifiable concentrate. Soilserv's Sevin® specifically designate "EC" on the label.

Solutions of 0.1%, 0.5%, 1%, and 5% a.i. made from Miller's Liquid Sevin gave 100% mortalities of A. fulica in drench treatments. A 30-minute dip treatment with 0.1% a.i. solution of Miller's Liquid Sevin also gave 100% mortality (Table VIII).

Thirty-minute dip treatments of 0.5% and 1% a.i. solutions of Soilserv's Sevin® 25% EC gave 100% mortalities of A. fulica.

The mortality performance of the carbaryl non-emulsifiable concentrates, Carin, Ortho WP, and Sevimol, was similar to each other. Dip treatments of Ortho WP and Carin at 0.1% and 1% a.i. gave 10% and 80%, and 60% and 90% mortalities of A. fulica respectively. Dip treatments of Sevimol 0.5% and 1% a.i. gave 50% and 100% mortalities respectively (Table VIII).

Methylene chloride and xylene, two common inert ingredients in EC insecticides, were tested to learn if they contributed to the molluscicidal activity of the carbaryl EC formulations. Both demonstrated a high degree of molluscicidal activity (Table VIII). Thirty-minute dip treatments with methylene chloride and xylene 0.6%, 1%, and 2% a.i. solutions gave 50-100% mortalities of A. fulica. Methylene chloride 0.3% a.i. in combination with Ortho Sevin WP 0.3% a.i. (carbaryl) gave 100% mortality of A. fulica in a dip treatment. Alone, a 0.6% a.i. dip treatment of methylene chloride gave 80% mortality and a 0.5% a.i. dip treatment of Sevimol (carbaryl) gave 50% mortality.

Both methylene chloride and xylene when used alone gave 100% mortalities in dip treatments of 1% a.i. A 0.6% a.i. dip treatment of xylene gave 50% mortality of A. fulica. Xylene 0.3% a.i. in combination with Ortho Sevin WP 0.3% and in combination with methylene chloride 0.3% a.i. (dip treatment) gave 80% mortality. Ortho Sevin WP 0.2% in combination with methylene chloride 0.2% and xylene 0.2% a.i. (dip treatment) gave 80% mortality.

The mortality effects of methylene chloride and xylene in combination with carbaryl appear to be additive. The two inert ingredients are molluscicidal to A. fulica.

Methylene chloride and xylene need to be tested further to determine their ovicidal effect on the eggs of *A. fulica*. At this point, one cannot know if it is the active ingredient (carbaryl), the inert ingredients (methylene chloride and xylene), or a synergistic and/or additive effect of the materials in combination that makes Miller's Liquid Sevin ovicidal to *A. fulica* eggs.

Miller's Liquid Sevin was phytotoxic (Table IX). Ortho Sevin WP, methylene chloride, and xylene when used alone were relatively non-phytotoxic (Table IX). This will reduce or restrict the use of Miller's Liquid Sevin as a regulatory treatment for the movement of plants.

The results of the Phase IV treated-foliage feeding tests against *A. fulica* showed that the younger the *A. fulica*, the sooner it was killed by "feeding" on Manoa lettuce dipped in 0.1%, 0.2%, and 0.4% a.i. solutions made from Miller's Liquid Sevin Insect Spray 10% (Table X; Figs. 16-20). "Feeding" is placed in quotation marks because it is highly probable that the *A. fulica* killed by coming in contact with the toxic ingredients (carbaryl, methylene chloride, and xylene) while crawling and feeding on the lettuce.

The low mortalities obtained from carbaryl 2%, 4%, and 8% a.i. baits (Tables II and III) suggests that the *A. fulica* in the treated-foliage feeding tests were killed by coming in contact with the a.i. solution on the treated lettuce rather than from eating the lettuce. It is possible that both contact and stomach poisoning actions were involved in varying degrees.

The regressions of percent mortality of $1\frac{1}{2}$, $2\frac{1}{2}$, and $3\frac{1}{2}$ months old A. *fulica* to days of exposure to lettuce dipped in 0.4% a.i. solutions made from Miller's Liquid Sevin Insect Spray 10% were 6.4, 2.69, and 3.26 units (%) of mortality/day of exposure respectively (Fig. 19). There was 1.3 units (%) of mortality/day of exposure of $1\frac{1}{2}$-month old A. *fulica* to letttuce dipped in 0.2% a.i. solution of Miller's Liquid Sevin (Fig. 16). There was no significant mortality of $1\frac{1}{2}$-month old A. *fulica* to 0.1% a.i. solution; $2\frac{1}{2}$- and $3\frac{1}{2}$-month old A. *fulica* to 0.1% and 0.2% a.i. solutions of Miller's Liquid Sevin (Figs. 16-18). There was 25.12 units (%) of mortality/day of exposure of one week old infant A. *fulica* to days of exposure to lettuce dipped in 0.1% a.i. solution made from Miller's Liquid Sevin (Fig. 20). Mortality/days of exposure was correlated to age of A. *fulica* and concentration of treatment solution.

There is no reason to believe that those compounds which gave a high mortality of A. *fulica* in the Phase I initial screening tests would not also give comparable mortality when used in drench or dip treatments for regulatory purposes.

The screening of candidate molluscicides has revealed five types of molluscicidal activity associated with A. *fulica*. The candidate molluscicide may have contact poisoning action, contact and stomach poisoning action, contact and stomach poisoning action but not fed on by A. *fulica* (undesirable or repellent), stomach poisoning action, and no poisoning action.

Other workers can use my point of departure as a starting point. Each compound that demonstrated molluscicidal action can be tested in depth to determine the extent of its molluscicidal activity.

In conclusion, the following statements and recommendations for the eradication of incipient infestations or small isolated infestations of _A. fulica_ can be made:

- Baiting alone is adequate for control but not for eradication.
- Utilization of both hand-collecting and baiting to kill or eliminate active reproducing adults (baiting and hand-collecting are equally effective and are complimentary).
- Utilization of ovicidal-molluscicidal drench treatments to prevent the eggs from hatching and to kill the infants, young, and possibly adults. Drench treatments will also serve to activate those _A. fulica_ in aestivation, making them vulnerable to hand-collecting and baiting.
- Utilization of the above steps will facilitate breaking the reproduction cycle. Those adult _A. fulica_ not eliminated by hand-collecting and baiting will become nonreproductive or sterile with time. The appropriate drench treatment will keep the eggs, infants, and young from becoming reproducers.

LITERATURE CITED

Abbott, R. Tucker. 1948. The spread and destructiveness of the giant African snail, Achatina fulica. Nautilus 62(1): 31-34.

Alicata, Joseph H. 1970. The Parasitology Laboratory of the Hawaii Agricultural Experiment Station: A review of its history and contributions (1935-1970). Research Report 193: 20-23, 36-38. Hawaii Agric. Experiment Station, College of Tropical Agr., Univ. of Hawaii.

Barry, B. D. 1969. Evaluation of chemicals for control of slugs on field corn in Ohio. J. Econ. Entom. 62(6): 1277-1279.

Basinger, A. J. 1935. Measuring the efficiency of materials used for snail control. J. Econ. Entom. 28: 903-906.

Bequaert, Joseph C. 1950. Studies in the Achatinidae, a group of the African land snails. Bull. Mus. Comp. Zool., Harvard, 105(1): 49-94.

Butler, G. D., Jr., and James Kim. 1959. Memorandum dated March 31, 1959, to Q. C. Chock: Experiments to evaluate several bait formulations for the control of the giant African snail - Honolulu, Hawaii - March 18-30, 1959. 6 pp. Terr. of Hawaii, Bd. of Commr. of Agr. and Forestry, Div. of Entom. and Marketing.

Chamberlin, J. L. 1952. Final report on an ecology and population study of the giant African snail on Tinian, Marianas Islands. 27 pp (mimeographed). Pac. Sci. Bd. of the Natl. Res. Council, Invert. Consultants for Micronesia. (Harvard U., Cambridge, Mass.)

Choy, Robert B. 1963. A study of the altitudinal distribution of giant African snails (Achatina fulica Bowdich) in the Makiling National Park and the forest tree species they attack. Philippine J. of Forestry 19(1/4): 99-107.

Cooperative Economic Insect Report. 1965. CEIR 15(6): 78. U. S. Dept. of Agr., Agric. Res. Svc., Plant Pest Control Division.

_____ 1966a. CEIR 16(3): 37. Ibid.

_____ 1966b. CEIR 16(17): 377. Ibid.

_____ 1966c. CEIR 16(43): 1018. Ibid.

_____ 1967. CEIR 17(5): 64. Ibid.

_____ 1968. CEIR 18(6): 56. Ibid.

_____ 1969a. CEIR 19(16): 77. Ibid.

_____ 1969b. CEIR 19(39): 754, 757. Ibid.

Crowell, H. H. 1967. Slug and snail control with experimental poison baits. J. Econ. Entom. 60(4): 1048-1049.

Esaki, Teiso and Keizo Takahashi. 1942. Introduction of the African snail, Achatina fulica Ferussac into Japan, esp. Micronesia, and subsequent developments. Kagaku Nanyo (Science of the South Sea) 4(3): 16-25 (in Japanese). (Complete translation by Toyohi Okada for Pac. Sci. Bd., B. P. Bishop Mus., Hon., pp 1-10.)

Gaaboub, I. A., I. M. Abales, and A. S. El-Khodary. 1972. The effectiveness of certain mosquito larvicides in comparison with the molluscicide, niclosamide against the schistosome-bearing snail Biomphalaria alexandrina, in the surroundings of Alexandria, Egypt. World Health Organization/VBC/72.368, WHO/SCHISTO/72.18 (unpublished document). 8 pp.

Getzin, L. W. 1965. Control of the gray garden slug with bait formulations of a carbamate molluscicide. J. Econ. Entom. 58(1): 158-159.

Ghose, Krishna Chandra. 1959. Observations on the mating an oviposition of two land pulmonates, Achatina fulica Bowdich and Macrochlamys indica Godwin-Austin. J. Bombay Natural Hist. Soc. 56(2): 183-187.

Herklots, G. A. C. 1948. Giant African snail, Achatina fulica Fer. Food & Flowers 1(1): 1-4. South China Morning Post, Ltd., Hong Kong.

Howitt, Angus J. 1961. Chemical control of slugs in orchard grass-ladino white clover pastures in the Pacific Northwest. J. Econ. Entom. 54(4): 778-781.

Howitt, Angus J. and Stanley G. Cole. 1962. Chemical control of slugs affecting vegetables and strawberries in the Pacific Northwest. J. Econ. Entom. 55(3): 320-325.

Hunter, P. J. and D. L. Johnston. 1970. Screening carbamates for toxicity against slugs. J. Econ. Entom. 63(1): 305-306.

Johnson, Richard G., Jr. 1969. Memorandum report to J. C. Haley dated Nov. 1: Summary of giant African snail, Achatina fulica Bowdich, activities from September 15, 1969 - October 31, 1969. 10 pp. USDA, ARS, Plant Protection.

Judge, F. D. 1969. Preliminary screening of candidate molluscicides. J. Econ. Entom. 62(6): 1393-1397.

Kekauoha, Willard. 1966a. Life history and population studies of Achatina fulica. Nautilus 80(1): 3-10.

_____ 1966b. Ibid. Nautilus 80(2): 39-46.

Kim, James. 1959a. Memorandum dated April 2, 1959, to Q. C. Chock: Metaldehyde spray test on Achatina fulica. 2 pp. Terr. of Hawaii, Bd. of Commr. of Agr. and Forestry, Div. of Entom. and Marketing.

_____ 1959b. Memorandum dated April 16, 1959, to Q. C. Chock: Cinder-mix pellets from Hilo. 1 p. Ibid.

Kondo, Yoshio. 1950. The problem of the giant African snail (Achatina fulica) in Micronesia: PART II, FINAL REPORT -- The giant African snail (Achatina fulica) in Palau (in part), Pagan, and Guam. 13 pp (mimeographed). May 26. Invert. Consultants Comm. for Micronesia, Pac. Sci. Bd. Natl. Res. Council.

_____ 1952. Report on carnivorous snail experiment on Agiguan Island; primary and secondary Achatina-free areas on Rota; and gigantism among Achatina on Guam. 49 pp (mimeographed). December. Pac. Sci. Bd. of the Natl. Res. Council, Invert. Consultants Comm. for the Pac.

_____ 1964. Growth rates in Achatina fulica Bowdich. Nautilus 78(1): 6-15.

Lange, W. H., Jr. 1950. Life history and feeding habits of the giant African snail on Saipan. Pac. 4(4): 323-335.

Lange, W. H., Jr., and G. F. MacLeod. 1941. Metaldehyde and calcium arsenate in slug and snail baits. J. Econ. Entom. 34(2): 321-322.

Lange, W. H., Jr., and R. H. Sciaroni. 1952. Metaldehyde dusts for control of slugs affecting Brussels sprouts in central California. J. Econ. Entom. 45(5): 896-897.

Lewis, H. C. and J. R. La Follette. 1942. Control of the brown snail in citrus orchards. J. Econ. Entom. 35(3): 359-362.

Mandal, T. K. and K. C. Ghose. 1970. Application of calcium arsenate: Histopathological changes & glycogen mobilization in Achatina fulica Bowdich. Indian J. Exp. Biol. 8(4): 332-333.

Mead, Albert R. 1961. The Giant African Snail--A Problem in Economic Malacology. Univ. of Chicago Press. 257 pp.

Meer Mohr, J. C. van der. 1957. Additional notes on the life-history of Achatina fulica Bowdich. Indonesian J. for Natural Sci. 112(II) (July - December 1956): 191-195.

Mitchell, Wallace C. 1973. Unpublished research.

Nair, M. R. G. K., N. M. Das, and Abraham Jacob. 1968. Use of metaldehyde dusts and sprays to control the giant African snail Achatina fulica Bowdich. Indian J. Entom. 30(1): 58-60.

Osborne, Evelyn M. 1971. A list of names to be used in Entomology Research Division manuscripts. 65 pp. September 1971. USDA, ARS, Entomology Research Division, Pesticide Chemicals Research Branch.

Pangga, Guillermo A. 1947. How to control the giant African snail. Plant Industry Digest 12(7): 28-30.

_____ 1957. Further studies on the biology, ecology and control of the giant East African snail (Achatina fulica Fer.). Proc. 8th Pac. Sci. Congress 3A: 1433-1452.

Peterson, George D., Jr. 1957. Studies on control of the giant African snail on Guam. Hilgardia 26(16): 643-658.

Rees, W. J. 1951. Giant African snail. Proc. Zool. Soc. London 120(3): 577-598.

Richardson, Henry H. and Herbert Roth. 1963. Ethylene oxide fumigants to eliminate quarantinable snail Cochlicella or Theba in cargo. J. Econ. Entom. 56(6): 836-839.

_____ and _____ 1965. Methyl bromide, sulfuryl fluoride, and other fumigants against quarantinable Cochlicella and Theba snails. J. Econ. Entom. 58(4): 690-693.

Roth, Herbert. 1971. Fumigation with ethylene oxide-carbon dioxide mixture for quarantine control of the giant African snail. J. Econ. Entom. 64(1): 341-342.

Schreurs, J. 1963. Investigations on the biology, ecology and control of the giant African snail in West New Guinea. 18 pp (typescript).

Somander, S. V. O. 1951. The Kalutara snail (Achatina fulica). Loris 5: 264-267.

Srivastava, P. D. and Y. N. and J. Singh. 1968. Observation on the control of Achatina fulica Bowdich, the giant African snail with metaldehyde. Indian J. Entom. 30(2): 175-176.

Sturgeon, Rita K. 1971. Achatina fulica infestation in North Miami, Florida. The Biologist 53(3): 93-103.

Weber, P. W. 1953a. African snail poison rock tests. 2 pp. March 2, 1953. Terr. of Hawaii, Bd. of Commrs. of Agr. and Forestry, Div. of Entom. and Marketing.

_____ 1953b. First progress report on African snail studies: Barrier Tests. p. 3. March 18, 1953.

_____ 1954. Studies on the giant African snail. Proc. Hawaiian Entom. Soc. 15(2): 363-367.

Williams, Francis X. 1951. Life-history studies of East African *Achatina fulica* snails. Bull. Mus. Comp. Zool., Harvard, 105(3): 295-317.